Environmentally Sensitive Maintenance for Dirt and Gravel Roads

Chapter 4: Basics of Natural Systems

4.1 Introduction

Today, road managers must operate and maintain public roads in a broad context that considers multiple social, political, and environmental objectives. This tough task is made more difficult by the fact that most roads were built within a much narrower context that focused only on short-term purposes such as engineering, cost, and convenience.

4-01 Many roads were built without regard to natural systems.

Through construction, our transportation systems were traditionally laid down across the entire fabric of the landscape. Nearly all roads were built without regard for the function of the natural systems that evolved in these locations. Roads built adjacent to and across streams, through wetlands, farms, and forests inevitably disrupted both surface and subsurface drainage, vegetation patterns, and native animal communities.

4-02 Environmental problems bear witness to our disturbance and disruption of natural systems.

Potholes, ruts, road washouts, bank failures, ditch blockages, and fallen trees bear witness to our disturbance and disruption of natural systems. In addition, typical environmental problems also appeared, such as muddy streams, deteriorated habitat, and changes in the number and type of both plant and animal communities. But efforts to address these problems without understanding their causes have often been a waste of money.

As previously stated, road management is an increasingly complex task where managers must balance human expectations against intricate natural systems. This chapter will introduce some basic guiding principals of natural systems so road managers can better understand the relationship between the roads and the environment. These basic guiding principles will focus on the three pertinent natural systems: streams, wetlands, and forest/upland areas.

Chapter 4 starts with an introduction to ecology and ecosystems. It will then provide more specific information on the three common ecosystems or communities: streams, wetlands, and forests/uplands, respectively. This information supports our objective to "arm the user with knowledge on basic principles of nature and natural systems…" so that we can apply that knowledge to our road maintenance programs through environmentally sensitive practices, resulting in better roads and a better environment.

4.2 Ecology, Ecoregions and Ecosystems

4-03 Physical factors such as geology, soil, hydrology, and climate shape the 'habitat'.

The term ecology stems from the Greek word "oikos," which means "house." Ecology can be defined as the study of interactions of organisms between one another and the physical and chemical environment. As indicated by the definition, all living organisms (plants, animals, fungi, and micro-organisms, such as bacteria and viruses) are dependent upon conditions present where they live (in their "house"). This range of ecological conditions, which describes where an organism lives, is termed "habitat." Habitat is defined by a wide variety of physical and biological factors. Physical factors, such as local geology (elevation, slope, drainage, rock type, etc.), soil (nutrients, stability, etc.), hydrology (precipitation, runoff, soil, moisture, evaporation, etc.), and climate (temperature, sunlight, day length, etc.), shape the setting in which biological organisms live. Biological factors, such as competition for food sources and mates, predation, disease, and social interaction, determines how well organisms survive and reproduce within the physical setting.

Ecologists have studied many of the interactions that take place between biological and physical systems, and based upon their findings, divided the landscape into ecoregions or areas with similar characteristics. These ecoregions reflect the physical factors (geology, soil, hydrology, climate) that help define their respective habitats, and in turn determine the type of animals and plants that live in that habitat. Geological provinces and ecoregions are closely linked. The comparison of geological and ecoregions maps demonstrates the boundary similarities. (Appendix 4. Case Study: Pennsylvania's Ecology illustrates this comparison in Figure A4-1 using the geology province map and an ecoregion map of Pennsylvania.)

Vegetation is heavily dependent upon the area's elevation, slope, drainage, stability, and nutrient availability conditions, in essence, the geology and soils. If plants from one ecoregion are planted within another ecoregion, they will most likely not do as well as they would have in their own ecoregion. This is because plants (and animals) have developed and evolved under a certain set of physical conditions characteristic of their ecoregion, and if these conditions are not met, then they will have a difficult time surviving. In some instance, road locations and maintenance practices create conditions unnatural to that ecoregion, causing survival failures in otherwise viable animals or plants.

4-04 Plants develop and evolve under the physical conditions of their ecoregion.

This ecoregion concept is critically important for "environmentally sensitive maintenance for dirt and gravel roads." Road managers must understand natural systems to adopt effective road maintenance practices that provide sustainable roads without hurting the environment.

One key is to use nearby natural systems as an example of what our project sites should look like and how they should function. Projects, whether construction or maintenance, will be more successful if they are modeled after nearby natural systems because nature has already done the research for us. These natural systems can be used to determine what slopes are sustainable for road and stream banks, as well as what plants grow well in a specific location. The relative size of local drainage features serve as a guide for sizing drainage structures for the roadway system. Projects modeled after natural systems will also look more natural and aesthetic compared to more sterile engineering designs. And, as we shall see, we can learn how to use these natural systems to actually aid us in more effective and efficient road maintenance

4-05 Ecosystems (Communities)

Ecoregions are broad areas that cover many different types of habitat, and because of this, ecoregions are often broken down into smaller units. Within each ecoregion, there are typically three types of ecosystems, or communities: streams, wetlands, and forests/uplands. The term upland commonly refers to areas of higher elevation that are well drained, covered with forests or cleared for farming or have reverted to meadows.

Each one of these ecosystems relate differently to maintaining dirt and gravel roads. In the stream ecosystem, sediments and their effect on stream life are a major concern. Sensitive plants and animals are a major concern with wetlands, in addition to other major benefits, such as flood storage. Strict laws and regulations govern roads built through and near wetlands so we can continue to receive these benefits. Finally, in forested or upland areas, improper trimming and clearing of vegetation associated with road maintenance causes a major concern and unwarranted expense.

4.3 The Stream Ecosystem (Community)

4-06 There are 3,692,830 miles of rivers and streams within the United States.

4.3.1 Introduction: According to EPA's National Water Quality inventory, there are 3,692,830 miles of rivers and streams within the United States. This vast network of streams is a tremendous natural resource. There are a number of important interactions between our dirt and gravel roads and our stream networks. Precisely because our roads and streams are so closely linked, road managers must be extremely sensitive to the well-being of the stream.

4.3.2 Basics of Stream Ecology: Stream ecosystems, or communities, are dependent upon a wide range of both physical and biological factors, as reviewed previously. These factors, how they are connected, and their importance to the stream will be discussed in the following sections.

4.3.2.1 Watersheds: Streams are situated in the bottom of their valleys, draining water from the surrounding higher landscape. This area drained by the stream is referred to by several interchangeable terms: watershed, drainage basin, or catchment area. Although we typically perceive streams starting where sufficient water has accumulated to form a channel, streams actually begin at the highest points within their

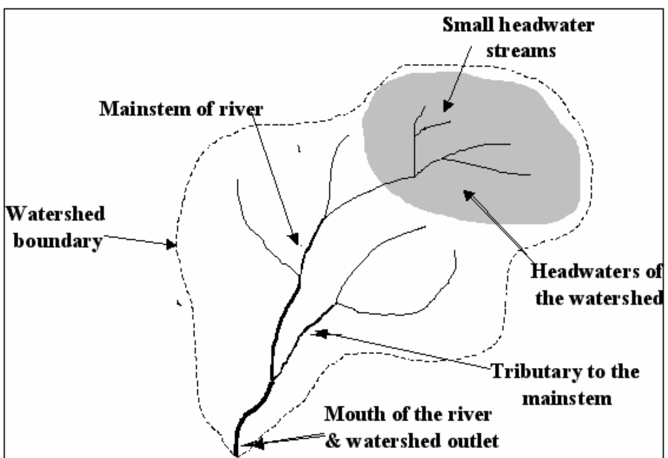


Figure 4-1 Watershed Features

watersheds, the point where precipitation first contacts the ground. Once precipitation hits the ground, gravity causes the water to flow downhill, first as a very thin sheet of water similar to a sheet of water flowing over a paved road. Irregularities in the ground surface break up this smooth flow, causing the water to accumulate in increasingly greater quantities. This water accumulation begins to cut a channel, first forming small rills, then gullies, and then becoming small streams. Small streams are formed in the headwaters portion of the watershed, as shown in Figure 4-1. Small streams join each other, accumulating more water until the flow eventually becomes a river.

Because streams obtain water from their watershed, activities that take place in the watershed can negatively affect the quality of the water entering the stream. If the stream receives polluted water, then the life in the stream will also be impacted. The pollution of our nation's waterways and water quality issues over the past 100 years has created much public resentment. In response to this pollution, laws were passed to protect our water resources as early as the Federal Rivers and Harbors Acts of 1890 and 1899. Pollution, and our knowledge of its impacts, has increased since these early laws, and additional regulations govern activities along streams in an effort to protect and preserve stream systems and the benefits that they provide. It is important to know about and work within these necessary legal restrictions when conducting road maintenance work.

Traditional management of our water resources has been based on political divisions (e.g., township, county, state boundary lines). Water, however, flows across these jurisdictional boundaries, making management and protection of this valuable resource difficult. Effective management must involve the challenging task of coordinating efforts between multiple political jurisdictions. One of the best ways to make the management of our water resources easier and more effective is to manage it on a watershed or catchment area basis. Because planning at the local level is often at too small a scale to address watershed size resource problems, local governments are strongly encouraged to communicate and coordinate control efforts with neighboring municipalities and county agencies.

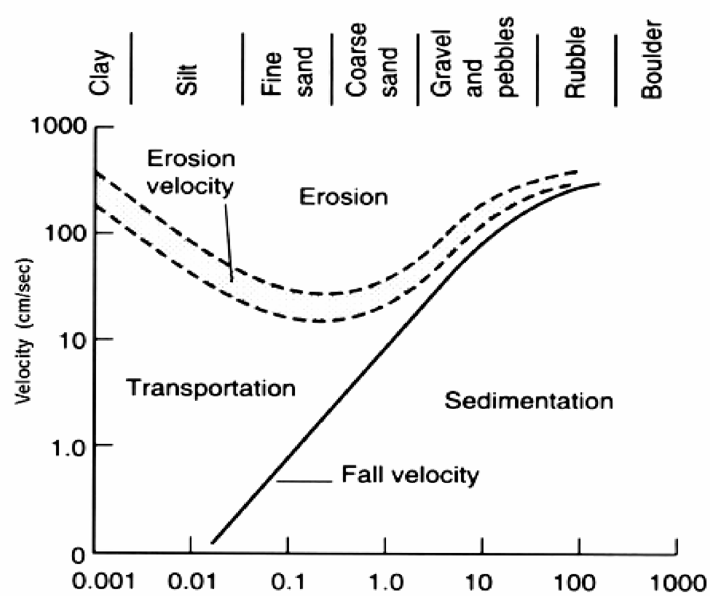


Figure 4-2 Average water velocities to erode, transport and deposit uniformly sorted particle sizes. Velocities between the dotted lines and higher will erode the indicated particle sizes. When velocities drop below the fall velocity line, there is insufficient energy to keep particles suspended in the water, so sedimentation occurs. Erosion velocities differ depending on the shape and bonding characteristics of the particles.

4.3.2.2 Stream Systems. As mentioned in our discussion of watersheds, streams are formed when water flowing downhill concentrates and forms a channel. The volume of water, the velocity, or speed, of water flow, and the characteristics of the underlying material influence the size, shape, and path of the channel. Although the information in this section refers specifically to streams and stream channels, these processes also explain and describe the interactions between water and sediment in drainage ditches.

Flowing water picks up (erodes) material from the bottom (bed) and sides (banks) of the stream channel. This eroded material is called sediment. The water's velocity determines how much material will be picked up, as larger sized particles, in general, require greater amounts of energy to erode or move them. Figure 4-2 shows the velocities necessary to erode, transport, and deposit uniformly sorted particle sizes. This figure also shows that clay sized particles require more velocity to erode than do larger, sand-sized particles. This is because electrical bonds associated with the clay particles help to hold them together, thus requiring more energy to pull this sticky material apart than to pick up the loose grains of the larger-sized sand.

The material that is eroded and carried by the water current is called suspended sediment. If the material is too large to be fully suspended in the water, it may either bounce (saltation load) or roll along the bottom (bed load), as depicted in Figure 4-3. When water velocities slow (e.g., when a mountain stream leaves a hilly area and starts across a valley floor), larger, heavier particles are the first to drop out of suspension and are deposited on the bottom of the stream. As water velocities continue to slow, there is less energy to suspend particles, and finer and finer particles continue settling to the bottom. This process is called sedimentation. Because clay is the smallest and lightest particle, once the stickiness is overcome and the particles are suspended, they remain in suspension longer and travel further than any of the other particle sizes. It can even take several days or weeks for clay particles to settle from perfectly still water.

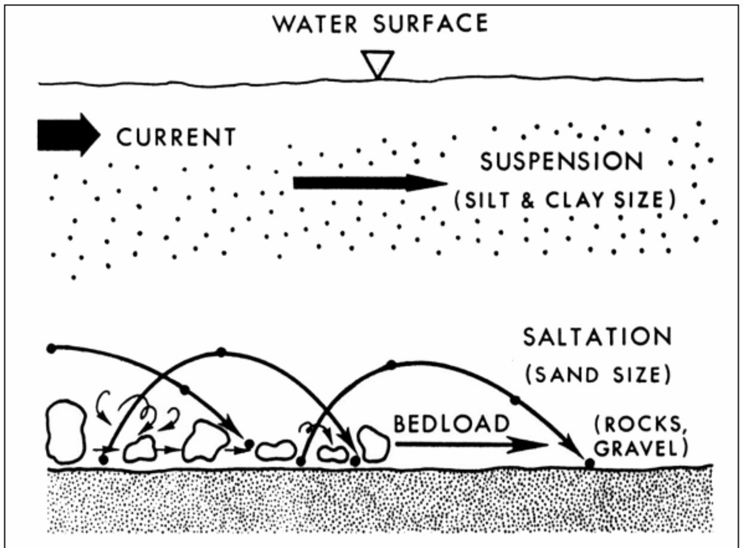


Figure 4-3: **Water transport various sized particles in various ways.**

Stream channels are dynamic because erosion and deposition processes change their form and shape (morphology) over time. They change both their cross-sectional profile (width, depth, and slope) as well as their 'plan-view' path. It is important to note that stream paths are not fixed in place; stream channels often migrate sideways, either incrementally by eroding their banks or by carving whole new channels through low-lying areas. These changes in the shape of the stream channel occur both site specifically as well as throughout the whole stream system.

4-07 Streams are constantly eroding, transporting, and depositing materials.

Natural channels are constantly eroding, transporting, and depositing materials. Normal daily flows tend to redistribute small amounts of materials within streams. Storm events, however, introduce large volumes of water in to the stream system, which can significantly alter the morphology of a river or stream by cutting new channels, eroding whole banks, and gouging out shallow river beds. Sediment generated during flooding from major storm events is often carried out of the channel by flooding waters, where it is deposited and stored on the floodplain. These sediments enrich floodplain soils with nutrients, which enable plants to grow well in a floodplain environment. The plants and their roots also help to trap and hold the fine sediments in place. Over time, however, rainwater washing over the floodplain may erode and return some of this sediment to the stream.

As streams continue to erode, transport, and deposit materials, human activities anywhere within the watershed can interfere with these natural processes, creating conditions that alter habitat and disrupt the aquatic life that lives in the stream. For example, poor maintenance of a dirt or gravel road may cause excess sediment to wash into an adjacent stream. Excess sediments will be carried downstream until the water velocity slows and sedimentation occurs.

Individual streams are part of a network of channels that extend the whole length of a watershed. Because networks extend from the top (highest elevation) of a watershed to its outlet (lowest elevation), changes in the headwaters of a stream can affect the entire network. For example, logging a hillside in the headwaters of a watershed can cause more storm water runoff to reach the stream at a faster rate than it ever has before (trees block water flow across the ground and help the water sink into the ground). This extra flow is added to the existing water and can lead to problems downstream. Suddenly the 24-inch culvert that you installed last year is no longer large enough to handle the extra volume of water, resulting in water backing up and flooding out the road. This extra volume of water can also cause additional bank erosion and the redistribution of sediments that destroy habitat and clog drainage facilities and bridges.

4.3.2.3 Hydrology. A major factor influencing stream systems is their source of water and its movements within the watershed. Hydrology is simply the study of water distribution or movement within the watershed. Precipitation landing within a watershed can enter the streams by two different pathways. The most obvious pathway is when surface runoff flows across the landscape directly into the stream system. The less obvious route is when it seeps (infiltrates) into the ground, where it becomes groundwater. Groundwater flows through the pore spaces between soil and rock particles, and shallow groundwater near the surface may eventually drain into a stream channel. Water may also follow a combination of these pathways. For example, precipitation may flow as surface runoff down a hillside where it settles into a depression. In the depression, it may infiltrate into the ground and flow as groundwater into a stream.

The speed at which water flows through a watershed and enters a stream system helps shape the channel and the habitat found within the stream. Surface runoff, especially after large storm events or when the ground is frozen, flows quickly over the land surface and enters the stream. This causes large amounts of water to enter the stream system within a short time period, exceeding the channel's capacity and resulting in flooding. Streams that receive a large portion of their water supply from surface runoff are susceptible to widely fluctuating water flows and levels. These fluctuating flows create a highly variable, stressful environment in which only specially adapted plants and animals may live.

4-08 Concentrated water flows cause many familiar maintenance problems.

Groundwater-fed streams have more stable flows and environments than surface fed streams. They fill slowly, accumulating groundwater as it makes it way through the tiny pore spaces in soil and rock. When large amounts of precipitation infiltrate into the ground and become groundwater, the surface runoff from the storm is drastically reduced. This water still may enter the stream system, but because it flows slowly through the ground, possible taking days, weeks, or months to reach the stream, stream flows become more stable. More stable stream flows tend to result in more stable channel conditions and in turn, offers habitat for plant and animals that are adapted to these stable conditions.

Several landscape factors influence water flow across and through the landscape. As will be discussed further in our sections on wetlands and upland communities, a watershed's vegetation usually slows the rate and decreases the volume of surface runoff by aiding infiltration of water into the ground. Plants are also able to diminish groundwater supplies by up taking water through their roots. Roads also influence water flow and can have a major impact on watershed hydrology. By cutting across the landscape, roads block, constrict, and divert both surface and subsurface drainage patterns, artificially acting to collect and concentrate flows. These artificially concentrated flows cause many of our familiar road maintenance problems, including washouts, rutting, and flooding. Alterations in subsurface hydrology can also lead to soft spots in roads where additional concentrated water raises groundwater levels and groundwater flow is blocked. These problems and others are discussed further and addressed elsewhere in this manual.

4-09 As turbidity increases, light penetration decreases.

4.3.2.4 Water Quality. Water in natural environments is not just pure water. As mentioned in the previous discussion on watersheds, precipitation falls to earth where it moves over and beneath the ground's surface, down through the watershed and into the stream system. As the water moves through the watershed, it picks up materials and transports these materials into the stream environment. Materials may be transported as suspended sediment or may become dissolved in the water and carried as dissolved load. The type and quantity of materials entering the stream system from the watershed influence the overall quality of the water. This water quality is often evaluated by testing the water for specific chemical and physical characteristics, such as nitrogen, phosphorus, pH, dissolved oxygen, temperature, color, and turbidity. Turbidity is the degree to which the passage of light through water is blocked by suspended sediment, the cloudiness of the water.

Both the geology and the land use influence water quality. The rocks and soil in the underlying geology of a watershed have always influenced a basin's water. Rocks and soils add nutrients and minerals as well as filter excess materials from groundwater and surface runoff. The type of natural vegetated cover and human uses of the land also influence a watershed's water quality. Land uses such as roads, farming, construction, homes, industrial facilities, and urban areas have caused excessive materials to enter and harm stream systems. In particular, massive amounts of sediment have been eroded due to changes in land use over the past 200 years. These materials may either wash directly into the stream system or become bound to sediment particles and carried into the stream while attached to the sediment. Both natural and artificial materials that wash into streams may include sediment, fertilizers (nitrogen, phosphorus), animal wastes, human sewage, road salts, pesticides, herbicides, other chemicals, oil, and gasoline. The large number of roads crossing streams, unfortunately, has also provided opportunities to dump garbage, tires, appliances, and all sorts of other solid waste into our streams.

Water temperature is an especially important component of water quality for headwater streams. The temperature of the water in these headwater streams is largely influenced by the source of water. Groundwater-fed streams are fed by a relatively constant supply of cold water. Surface runoff-fed streams are fed by intermittent flows of water following storm events where the water flows across hot land in the summer and the cold (frozen) earth in the winter. These surface runoff streams have an irregular supply of water whose temperatures varies widely with ambient temperatures. Vegetation along streams is also an important temperature influence because it helps to moderate water temperatures. In the summer, shading of streams by adjacent vegetation prevents warming, and in the winter months, forests can trap warmer air in valleys to delay cooling.

4-10 Life in a Stream

4.3.2.5 Stream Life. There are a wide variety (diversity) of organisms that utilize stream habitats, and each stream contains a mix of different species. This mix of species makes up the stream community. Types of organisms include plants, insects, crayfish, mollusks, fish, reptiles, amphibians, spiders, birds, and mammals. Some aquatic plants are microscopic and include things such as plankton and algae. Larger aquatic plants are very diverse, with some spending their life floating in the water, while others live by attaching to soil, rocks, or plants. Many different insects spend at least part of their life cycle underwater (the larvae stage), including dragonflies, mayflies, stoneflies, caddisflies, beetles, and true flies (e.g., gnats, midges, black flies, horse flies, and crane flies). For example, mayflies live in the bottom of streams for a year before emerging as adults to reproduce and die within 2 to 3 days. Although numbers are swiftly declining, freshwater clams and mussels are important stream organisms. Streams can contain a wide diversity of fish, including minnows, sculpins, perch, trout, bass, and sunfish. Turtles (reptiles) and frogs (amphibians) are also found living in and near streams. Birds, such as herons, ducks, and hawks, frequently live along streams. Streams also provide habitat for mammals such as river otters, raccoons, deer, and beaver.

4.3.2.6 Stream Food Webs. All living organisms need a source of energy (food) to survive. In general, plants get their energy from the sun and produce their own food. Animals, on the other hand, get their energy from three different sources. One group of animals, the herbivores, gets their energy or food from the plants they eat. The second group of animals, the predators, eats other animals for their food energy. The third group are the decomposers, who get their energy from plant and animal remains. In stream systems, aquatic plants utilize sunlight and nutrients absorbed from the surrounding water and soil to help them grow. The energy found in aquatic plants, and sometimes more importantly energy from bank-side and upland vegetation (**outside inputs**), provides food for aquatic insects and some fish. While some fish and insects use plant material for food, many others are predators and gain their energy by eating other animals. This concept of who eats what and whom was originally known as a food chain, but biologists have realized that it is more complex than a simple chain of events. The interactions between who eats what is extremely interconnected and is more like a food web than a chain.

4-11 "Outside Inputs" are essential to a stream.

Outside inputs in the form of plant and plant material falling into the stream form the base of the stream food web in headwater streams. The stream's inhabitants break down this plant material and process it in a number of ways. Bacteria and fungi attack this plant material initiating the decomposition process by beginning to break down the plant material, and freeing nutrients for other organisms within the stream system.

Algae and plankton within the stream utilize nutrients, fungi and sunlight to grow. In turn, these plants provide food for other organisms, such as aquatic insects. Aquatic insects play a very large and important role in the aquatic food web. These insects are generally in their larvae stage of development. One group of insect larvae are grazers and wander around grazing and scraping algae and bacteria growing on the rocks and decomposing plant materials. Another group are shredders, tearing up and eating leaves and other plant material that has fallen into the stream. The filtering group strain small particles of suspended debris from the moving water. And finally, there are the predators (both larvae and adults) who eat other insects and small fish.

4-12 Fish are an important part of the aquatic food web.

Fish are also important in the aquatic food web. Like the insects, fish have also become adapted to certain diets. Most stream fishes, like the trout, eat a variety of aquatic insects, while others, such as the northern pike, prey upon smaller fish for their survival. Other types of fish obtain their food from plants, decomposing material from the stream bottom, or are parasitic to other fish. All of this interaction of the various organisms illustrates the complexity of a stream food web.

Stream systems also play an essential role in many terrestrial food webs. They provide vital habitat for creatures to catch food and obtain water. Many important, game and non-game species are directly dependent on the use of streams and the organisms within for survival. And we cannot forget that streams play a role in the human food web, as attested to by many anglers.

4.3.2.7 Outside Inputs. We need to further emphasize the importance of outside inputs. Upper elevation streams are usually small, steep-sloped, fast moving streams.

These smaller headwater streams are less dependent upon materials generated within the stream and more dependent upon the outside source of nutrients and food to support aquatic life. Overhanging branches and bank-side vegetation serve as their primary source of nutrients. Leaves, branches, twigs, roots, and fruit fall into and are washed into the water and, as mentioned previously, become the basis for a food web in the stream. Thus, these outside inputs become vital to the health of the stream. The overhanging vegetation along the stream edges also shades the water so algae dependent on sunlight does not grow and is therefore not readily available as a food source for aquatic life. Shading also helps to moderate swings in temperature, which is an important benefit during hot summer days.

4-13 Clearing streambanks has many negative effects on streams.

Human activities can interfere with this critical component of the food web by clearing vegetation from along the stream banks. Unfortunately, clearing stream banks has been a traditional form of stream bank maintenance. This practice was thought to be beneficial for a number of reasons, including that it cleared the floodway, improved drainage, was easy to maintain, and looked cleaner.

We now realize, however, that there are a number of problems associated with this traditional practice. These clean stream banks in fact shortchange the start of the food web, starving the entire system. In addition, without the vegetation to shade the stream, water temperature increases, and native organisms may not be able to tolerate this increased temperature. Clearing stream banks reduces the number of places for aquatic organisms to live because there are fewer roots and branches that extend over and into the stream. The bank side vegetation also helps slow the velocity of surface water and prevent erosion of the banks into the stream. Finally, without the vegetation along the stream to dissipate energy, trap sediment and floating branches and debris, this material can end up collecting and blocking openings of culverts and bridges or other drainage facilities. We will discuss alternative practices to the traditional stream bank cleaning in Chapter 6.

This manual focuses predominantly on these headwater types of streams as they are the most likely streams to interact with dirt and gravel roads. Impacts to these streams, however, which serve as a source of water, sediments, nutrients and biological organisms for the stream system, can and will impact the larger downhill streams into which they run.

4.3.2.8 Stream Habitat. Each plant and animal species needs a certain set of physical and biological conditions to survive. The area within the stream where these conditions are present is the organism's habitat. Stream organisms have adapted to these conditions and subsequently have become dependent upon these habitat conditions for survival. If one or more of these factors are missing, then the organisms dependent on those factors will have a harder time surviving. If the change is too great, the organism will die.

The suitability of the habitat also influences the abundance of a species. Abundance is critical because organisms need to be able to find mates to reproduce. If members of the same species are not abundant, fewer offspring will be produced, starting a downward population spiral. A decline of a species is significant for two reasons. First, as a living organism each individual and species has an inherent value. Second, declining populations of a species may upset delicate food webs by creating shortages for other species dependent on them for food, creating an imbalance in those populations, further disrupting the entire stream ecosystem.

4.3.3 Stream Management and Protection Goals. Streams are viewed as a public natural resource and, as such, are protected under various federal, state, and local laws and regulations in addition to many state constitutions. This protection covers the purity (quality) of the water as well as the organisms living in the stream. To this end, one of the primary goals of managing and protecting streams is to maintain a healthy and naturally producing fish community. Natural reproduction of fish is an important goal, and fish are dependent upon a clean, healthy stream environment in which to live. The lack of a naturally reproducing fish community is often an indication that conditions within the stream have degraded.

4.3.3.1 Indicator Species and Community Composition. Effective stream systems management requires some kind of indicator to help managers measure conditions within the stream. Although stream biologists have a wide range of tools and tests that can be performed to help measure stream health, stream ecology is a complex science. Stream ecologists have a strong understanding of the processes and interactions that take place in streams, but there is still much to be learned about these systems. Biologists have learned that instead of trying to monitor all the conditions that organisms require to survive, they can monitor the population of certain existing species and the community composition within the stream environment. These indicator species are sensitive to changes within the stream system, and if one of their habitat and resource needs is impacted, then changes in species abundance will indicate to biologists that something is wrong within the stream. Thus, indicator species are analyzed in the context of the overall abundance of organisms in assessing the condition of the aquatic system.

Trout are frequently used as an indicator species within headwater streams because, as a top predator, their survival is dependent upon a broad range of stream components. Some of the habitat needs of

4-14 Trout is a water quality indicator species. ***(Photo courtesy of Trout Unlimited)***

trout include cool, clean, well-oxygenated water, suitable invertebrate food sources, cover to hide from other predators and to rest, and spawning sites with gravel beds.

The life cycle of trout is important for their selection as an indicator species. If we look at the brook trout as a common primary species, these trout use their tails to dig nests in gravel streambeds in October and November of each year. The eggs are deposited and then fertilized before they are covered over with loose gravel. These nests need large amounts of cool, clear water flowing through the gravel as it supplies the eggs with oxygen dissolved in the water and carries away waste products produced by the developing eggs, as illustrated in Figure 4-4. This is a critical period for the new trout population because sediment deposition at this point can smother and kill the entire year-class of fish. If all goes well, these eggs will then hatch in March and April.

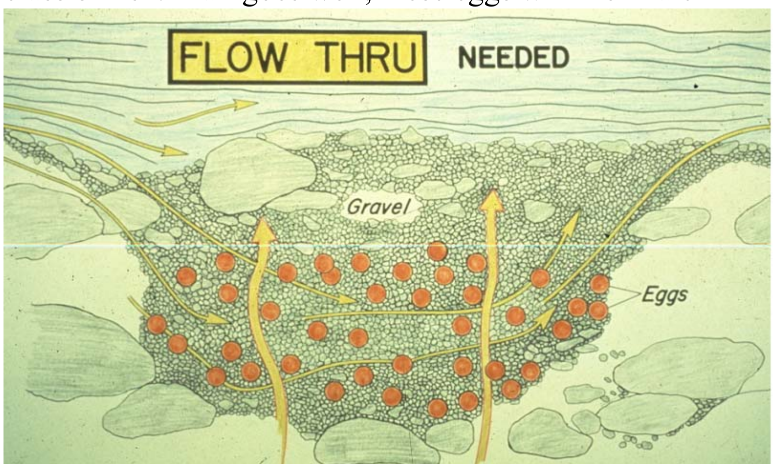
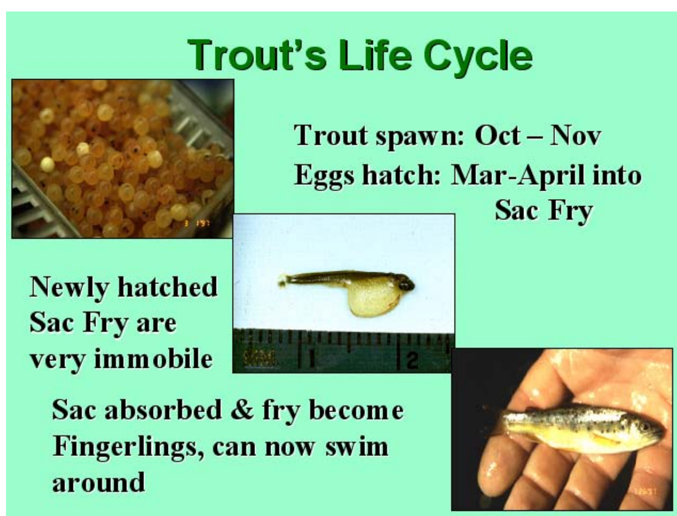


Figure 4-4: Trout eggs need clean flowing water for oxygen

Once the eggs hatch, the trout are initially called sac-fry because they carry their first month's supply of food in an attached yolk sac. At first, this yolk sac is quite large in relation to the size of the fish, which limits the ability of the sac-fry to move about and escape predation. The yolk sac is gradually absorbed during the first month of the fish's life. After the yolk sac has been absorbed, the trout are then called fingerlings. These fingerlings are increasingly mobile and look for minute particles of food. Fingerlings will grow as juvenile trout until they reach sexual maturity at about one to three years of age. Maturity typically corresponds to about 8 inches in length, but depends on environmental factors such as food supply and stress.

Hatching trout fry are typically abundant, but because of the harsh competitive stream environment, less than one percent of the hatched fry will live longer than one year. As will be further discussed, sediment is one of the major environmental factors that decimate the newly hatched young of the year's trout population. Once past this one-year milestone, the death rate of young trout declines sharply because the older and larger trout are better equipped to survive.



4-15 A Trout's Life Cycle

If done improperly, the initial grading of dirt and gravel roads in the spring time with the possible resulting sediment can totally wipe out an entire one year's population of newly hatched sac-fry trout for a nearby stream.

4-16 The stonefly larva is another indicator species.

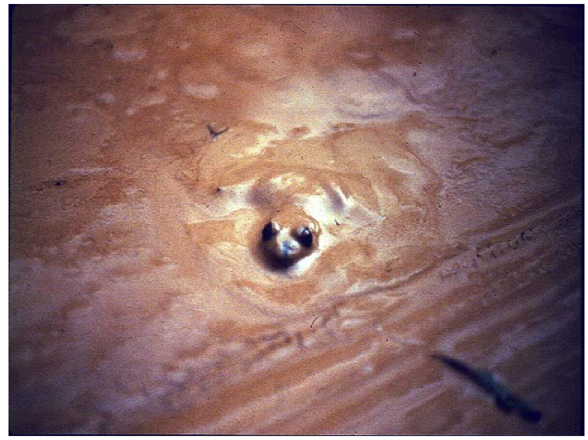
Other useful indicator species of stream health are the "macroinvertebrates" such as stoneflies, mayflies, and caddisflies. Some of the stonefly species are particularly sensitive to changes in water quality and methods have been developed to use these insects to evaluate stream health. In general, the public is less aware of the importance of stoneflies and other macroinvertebrates as indicator species for a healthy stream because they are harder to identify and are definitely less charismatic and less tasty than trout.

4.3.3.2 Stream Evaluation. State environmental agencies routinely monitor streams to ensure water quality and overall stream health. These agencies conduct biological and chemical surveys in an attempt to measure habitat conditions and see what pieces of the food web are present. This generally involves various techniques such as the use of electro-fishing gear to shock and temporarily stun fish, which are then collected, identified, measured, weighed, counted, and released. Various methods are used to collect, count, and identify invertebrates living in the streambed, floating in the water, and hiding in the vegetation. Data collected from these surveys are then analyzed and used to make management decisions.

4-17

4.3.4 Impact of Erosion and Sediment on Streams. Excessive erosion impacts streams in a number of ways. Many of the physical effects, such as bank erosion and channel migration, have been discussed in Section 4.3.2. Sediment generated from this excess erosion, however, critically harms the stream system as will be discussed here.

As we stated earlier, sediment in stream systems occurs naturally. Although these natural occurrences can be devastating, stream channels and stream life are more adapted to these natural influxes of sediment and can usually recover appropriately. It is the excessive amounts of sediment and selective particle types and sizes (commonly fine silt and clay) that end up in stream systems as a result of human activities that disrupt the stream ecosystem beyond their ability to recover. These disruptions can cause the original habitat to become unsustainable for the native organisms. These organisms will either die off or move to more suitable habitat. As the former occupants vacate this new habitat, new organisms that prefer the altered habitat will take over. The original nature and character of the stream will have been altered, perhaps changing the stream from a high-quality trout stream to a less valuable and productive stream polluted with what sportsmen call "trash" fish.



4-18 Excessive sediment causes distress for the stream's inhabitants.

Timing of sediment and erosion events is not spread evenly over the course of a year. These events are highly seasonal, with heavy rains and stream flows coinciding with spring construction and road maintenance activities. This combination of events leads to a large percentage of the year's total sediment ending up in stream systems within a short time period during these spring months. During other times of the year, generally drier weather conditions and better established vegetation that is able to hold soils in place or filter sediment from runoff, result in less erosion and sediment into the streams. Although not always practical, shifting human activities (ditch and bank repair) from the spring to the summer or fall months can significantly reduce the sediment pollution entering streams.

However, even modest amounts of sediment entering streams during periods of drought or low-flows may cause problems. During drier periods, many streams are subject to low-flow conditions, with water only present in the deepest part of the stream channel. Summer storms can cause flash flooding and sudden influxes of sediment from disturbed earth into the stream. These floodwaters can quickly recede, leaving water levels low, with much of the sediment recently being left behind in the deeper parts of the channel. These sediments remain for longer periods and reduce living space for aquatic organisms. This can be a real problem because it occurs at a time when water temperatures and other conditions are also very stressful.

4.3.4.1 Suspended Sediment (Turbidity). Earlier in this chapter we talked about suspended sediment and the fact that fine particles stay suspended for much longer periods of time than larger particles, and clay can stay suspended for days and weeks in still water. Once sediment is suspended in the water, it interferes with the habitat needs of both plants and animals. For plants, the sediment particles suspended in the water increase the turbidity of the water, blocking light as well as decreasing the depth to which light penetrates. Decreasing light, the source of energy for plants, results in less food production for plants and less plant growth. With less plant growth, there is less food available at the bottom levels of the food web. This food shortage can cascade through the food web, resulting in less food for top predators like the trout.

4-19 Suspended sediment interferes with both plants and animals within the stream.

Suspended sediment also impacts the aquatic insects and fish directly. Many fish and insects rely on their vision to detect prey and help avoid predators. As the suspended sediment decreases the visibility through the water, organisms will find less food and have a decreased ability to avoid being eaten. Fish and many types of insects breathe underwater by using gills to gather dissolved oxygen from the water. Gills are sensitive organs and suspended sediment can clog them, making it harder for the fish to breathe. Gills are also subject to abrasion from sediment particles. Sediments are particularly harmful to the relatively immobile sac-fry. These physical impacts to aquatic organisms are likely to make it harder for the individuals to find food, eat, and grow normally. With abnormal growth, organisms do not have the energy to fight off disease or to reproduce.

4-20 Embeddedness refers to the sediment filling in all the nooks and crannies in the streambed.

4.3.4.2 Sedimentation (Embeddedness). As water velocities slow within the stream environment, sedimentation occurs. The primary impact of excess sediment in the channel is the altering of habitat. The sediment settles down into the nooks and crannies between the gravel and rock substrate. Insects and small fish need these spaces to graze algae, hide from predators, hunt prey, and as shelter from the faster flowing currents above. Filling in these spaces with

4-21 Contaminants attached to sediment particles further degrades water quality.

sediment reduces the amount of living space available. Some plants and animals may also be buried and suffocate. Sedimentation is particularly harmful to trout reproduction because it kills the eggs while they are incubating in the gravel nests over the winter months.

This filling in of the nooks and crannies in a gravel streambed by sediment is referred to as embeddedness. A typical trout stream is usually about 30% embedded, while one that is completely buried by sediment would be described as being 100% embedded.

4.3.4.3 Attached Contaminants: Another impact of sediment on streams stems from the materials such as road salt, fertilizers, pesticides, oils, greases, and other toxic compounds that are often attached to the sediment particles. Once in the water, these attached compounds may degrade water quality.

4.3.5 Fish Constituency: Fish, unlike many other organisms in the stream environment, are unique in that they have advocates who represent them – the sport fishermen. Angler groups have organized at the local, state, and national levels, where they effectively lobby for government action. These groups, such as Trout Unlimited and B.A.S.S. (Bass Angler Sportsmen's Society), act as watchdogs to protect their fishing interests and aquatic resources. These groups can be a source of positive support for local governments or can make life difficult if inappropriate actions threaten our aquatic resources.

4-22 Anglers are avid fish advocates and can be a positive resource.

Anglers, however, do not always have a positive impact on the stream ecosystem. In their efforts to pursue their interests, they frequently create and use stream access points, footpaths, and car pull-offs. These places can often become a source of erosion and sediment or even interfere with erosion control measures that local governments have already put in place.

Just as when dealing with any group of stakeholders, whether they are landowners, businesses, environmental groups, or angler organizations, the most effective approach is to collaborate, or work together. Collaboration between local governments and angler groups offers tremendous potential. If these stakeholders are included in the decision-making processes, they may be able to add constructive and helpful suggestions, provide resources to aid projects in the form of funds, materials or people, and positively influence other groups, agencies or elected officials as needed. Many of these groups have vast volunteer resources that can be tapped for construction and maintenance projects. It is also an additional opportunity for the community to become more knowledgeable about road maintenance concerns, activities and budgetary limitations.

4-23 Anglers can also have negative effects on stream ecology as stream access points, car pull-offs, and footpaths become erosion sources.

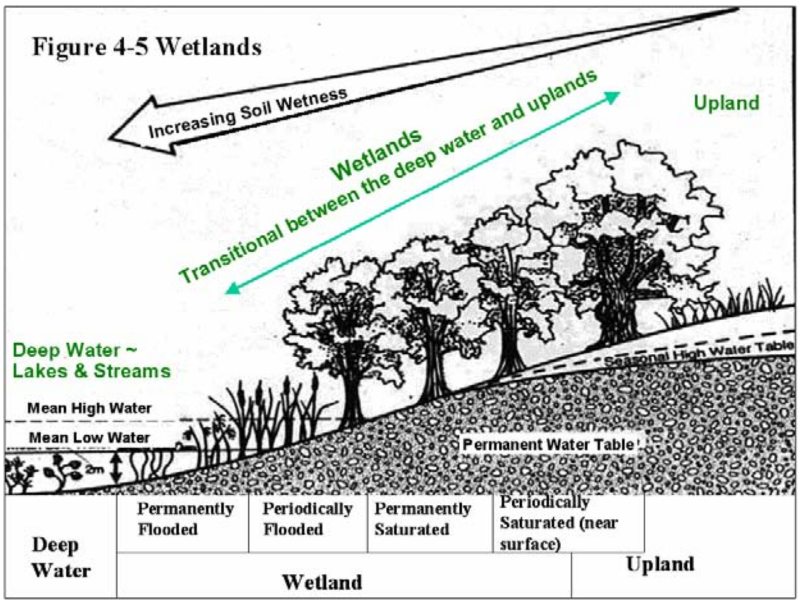
4.3.6 Stream Ecosystem Summary. Streams are an important natural resource. Stream communities are dependent upon the types of physical and biological habitat present within the stream system. Stream flows and water quality conditions shape this habitat and are strongly influenced by both the watershed's underlying geology and land use. Trout and macroinvertebrates, such as stoneflies, are considered good indicators of the health and quality of our headwater streams, as they are sensitive species dependent upon a number of factors that are likely to be impacted by adverse conditions within the stream system. Human activities, such as road maintenance, construction, logging, agriculture, development, and industry, can threaten the health of our streams and the organisms that live there. Excessive erosion and sediment from dirt and gravel roads is one of the primary threats to our streams, altering the entire stream ecosystem. Collaboration with stakeholders, such as anglers, farmers, and landowners, can help alleviate some of the problems and benefit local government in a variety of ways, especially in helping in the planning, construction, and maintenance of environmentally sensitive practices and projects.

4-24 Wetlands are important ecosystems.

4.4 The Wetland Ecosystem (Community)

4.4.1 Introduction: The wetland ecosystem or community is an important one, with wetlands currently covering over one hundred million acres of land in the lower 48 states. Although the word "wetland" seems to conjure up visions of wasteland swamps inhabited by undesirable creatures or fears of stifling regulations, wetlands provide valuable services and functions that are beneficial to both humans and the environment. This section will define and describe wetlands, discuss the history of management, regulations and wetland loss, introduce the valuable benefits derived from wetlands, and help road managers recognize wetland areas in order to avoid conflicts with existing regulations.

4.4.2 Definition of a Wetland: Under the Federal Clean Water Act, a wetland is defined as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."



Simply put, a wetland is an area that meets a certain set of soil, plant, and moisture requirements. So there are three basic characteristics common to all wetlands:

a) For at least part of the year, water must be present at or near the ground's surface.
b) Plants must be adapted for wet soil conditions.
c) Soil types must have developed under saturated conditions.

Wetlands are often the transitional area between the deep water and the uplands and can include permanently flooded areas to periodically flooded areas to permanently saturated areas to periodically saturated areas, as depicted in Figure 4-5.

4.4.3 Wetland Basics. A number of environmental factors affect these three wetland characteristics. For example, the amount of water found within a wetland can be influenced by either surface water or groundwater. The source of water plays an important role in providing outside nutrients to wetland systems. The underlying geology and topography of the landscape can influence the location and formation of wetlands. Geology also dictates the rock types that serve as parent material for the initial wetland soils. These mineral soils, however, are often buried under thick layers of organic peat and muck common to many types of wetlands. These moisture and soil factors, in addition to climate characteristics, directly influence the types of vegetation that are present within the wetland. The water in a wetland is directly responsible for forming the hydric soils.

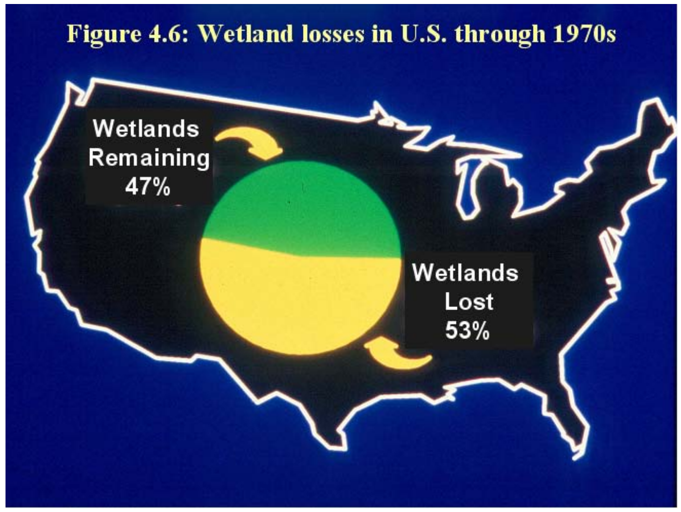
A hydric soil forms when soil is saturated with water for extended time periods. There are a number of biological and chemical processes that take place in soil that influence its formation and the types of plants that it is able to support. In drier soils, oxygen is typically abundant and leads to the formation of upland soils. When soils are saturated, however, natural processes deplete oxygen from the soil and produce very different wetland soils. Many wetland soils also have a much higher percentage of organic matter (decaying plant and animal life, etc.) than do upland soils, a factor that greatly increases the availability of nutrients and food for many wetland plants and animals. These hydric soils also have visible characteristics making them readily identifiable. Hydric soils mark wetlands; recognize the soil and you identify a wetland. The details of wetland recognition will be discussed later.

Wetland plants are those plants that have adapted to life under wet conditions. These plants have taken on a wide range of forms, from pond lilies to trees, in order to take advantage of the many different types of wet habitat. The major difference between these wet habitats is the variation in the amount or depth of water, which changes along an elevation and moisture gradient. For example, pond lilies can only grow in three to four feet of water, while red maples only tolerate periodic saturation. The moisture conditions within each of these habitats fluctuate according to seasons and weather patterns from year to year, with some locations wetter during the winter and spring months than during the warmer months. This variation in moisture or water levels is important because many of the wetland plants, especially grasses and herbs, require drier periods to produce seeds and germinate. Additionally, just as with stream systems, the variability of conditions within each habitat helps maintain a broader mix (diversity) of plant and animal species.

The presence of wetlands is dependent upon a delicate balance between the right soil, water, and vegetation characteristics. While natural variation within a wetland is normal and desirable, human induced disturbances can disrupt wetlands beyond their ability to recover. Human activities near wetlands may alter the flow of water into and out of wetlands, and/or lead to excessive inputs of sediment, nutrients, and chemicals. Care should be taken while conducting road construction and maintenance activities to prevent both short- and long-term impacts to these delicate ecosystems. It is important to note that wetland ecosystems are protected by stringent state and federal laws that restrict activities in and around these areas, as will be discussed in Subsection 4.4.4.2.

4.4.4 Wetland Management. Historically, as mentioned, wetland areas have received a bad reputation as dismal, disease-ridden, unproductive wastelands. As early as the Swamp Land Act of 1849, Congress encouraged draining and filling wetlands for development. Since then, in the name of progress, amazing efforts were put forth to drain and fill vast marshes and swamps to give these lands a purpose. These former wetlands were converted for residential, agricultural, and industrial uses.

These negative attitudes towards wetlands, however, have begun to change over the last several decades. We now realize that wetlands provide many physical, mechanical, and biological benefits that are useful not only to the natural environment, but to humans as well. Consequently, we have begun to protect wetlands and even replace some of the ones that have been lost to development. So the management of wetlands has come full circle over the last century. Undisturbed wetlands are now viewed as very productive, valuable natural resources for many reasons as will be reviewed in Subsection 4.4.5.



4.4.4.1 Wetland Loss. Over half of our original wetlands in the United States have been drained and converted to other uses. Major wetland losses occurred from the mid 1950s to the mid 1970s, with the rate of loss decreasing since then. Various factors have contributed toward this decline in wetland loss including the adoption of wetland protection laws and regulations. "Public education and outreach about the value and functions of wetlands, private land initiatives, coastal monitoring and protection programs, and wetland restoration and creation actions have also helped reduce overall wetland losses," according to the U.S. Environmental Protection Agency.

We now understand that wetlands provide many beneficial services and host the most productive habitats on earth. Wetlands, however, can be harmed by many different human activities including draining, dredging, stream channelization, filling, diking and damming, logging, mining, tilling for crops, and miscellaneous pollution discharges. The conversion of wetlands for development and agricultural purposes has probably resulted in the largest loss of wetlands. The loss of wetlands results in a loss of all the benefits derived from them. And all wetlands are important, no matter what size, location, or quality.

4.4.4.2 Regulatory Protection. The regulatory protection of wetlands began early in the 1900s when people began to recognize their value as breeding and fishing habitat for waterfowl. One of the early protection measures was the establishment of many National Wildlife Refuges in which wetland habitat was protected and enhanced for waterfowl and other water birds. During the years since this initial recognition of the wildlife value of wetlands, scientists, policy makers, and the public have also realized that wetlands provide society with many other benefits.

In the 1960s and 1970s, both the federal and state governments began to enact laws that protected wetlands. There are a number of federal agencies that work to protect our wetland resources, including the Army Corp of Engineers, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. D.A. Natural Resources Conservation Service, along with the corresponding state and local agencies. This list of agencies represents a broad spectrum of program areas, ranging from navigation to water quality and from wildlife management to soil conservation. This spectrum thus represents the complex array of issues associated with the protection of wetlands and each agency is responsible for portions of our federal and states wetland regulations.

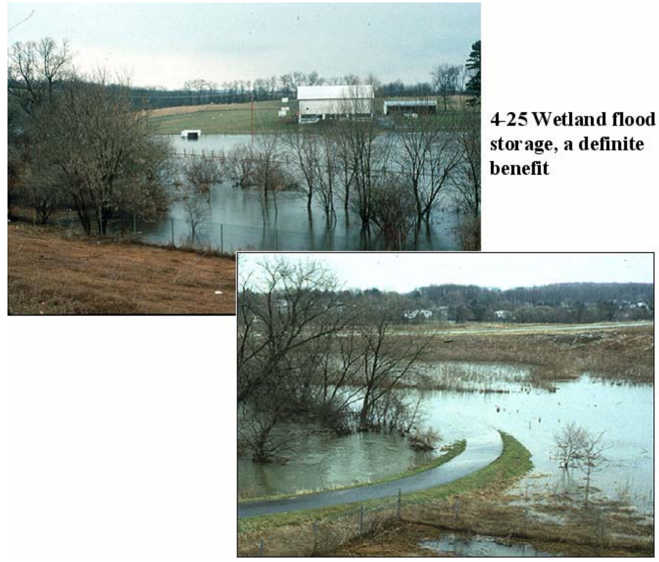
The regulatory environment at the time these wetland laws were enacted utilized the permitting process as a major tool to protect wetlands. This system of permits remains in place today. The permitting process is not intended to stop work activities; rather, it is designed to help people learn about wetland benefits as well as methods to lessen the impact of their activities on these important natural resources. In essence, permits are agreements between regulatory agencies and applicants governing work activities in and near wetland areas and outline necessary protection measures. Permits limit the loss of wetland area and help protect existing wetlands from excessive erosion and sedimentation, disruption of wetland hydrology, and pollution from sources such as mine acid drainage, toxic substances, and nutrient runoff. When necessary, permits also provide regulatory agencies with a basis for levying fines and forcing remedial action against those who have failed to live up to the permit's terms.

These regulatory agencies also have procedures for dealing with people who either intentionally or unintentionally harm these valuable natural resources. Local governments and road managers cannot afford to be ignorant about the value of these resources, since ignorance is not a defense against the penalties that may be imposed. The replacement, or mitigation, of wetlands is an expensive prospect, with engineering, land purchases, construction, and operational costs reaching into many thousands of dollars per acre.

Wetlands are also protected by many private groups. Conservation groups acquire land and provide education and volunteers at local, state, and national levels. Several major conservation organizations include The Nature Conservancy, Ducks Unlimited, the National Audubon Society, and the National Wildlife Federation. While these groups do not have the authority to develop their own regulations, they are considered "watchdog" groups and actively advise regulatory agencies of possible violations. Many of these groups also purchase property to protect and preserve sensitive habitat and /or species. Litigation is likely to be a possible response in a case where one of these properties is threatened by off-site sources of disturbance.

4.4.5 Wetland Benefits. Many valuable benefits are associated with wetlands. It is important, therefore, to become familiar with these benefits so that we can take a common sense approach when dealing with roads and wetlands. The following subsections describe the major benefits derived from our wetlands.

4.4.5.1 Floodwater Storage. A significant wetland benefit is the role that they play in floodwater storage. Since many wetlands form in low-lying areas, they are often the first areas to receive water when surface water runoff fills the streams to overflow their banks. The vegetation in these wetland areas slows the movement of the floodwaters, which are temporarily adsorbed, or held back, by the wetland. The wetland acts like a sponge, holding the excess storm water. As time passes, water is slowly released from its temporary storage within the wetland and drains either into the ground to become groundwater or back into the stream network. An engineer's "hydrograph" shown in Figure 4-7, which depicts the amount of flow during a storm time period, illustrates the flood storage benefit of wetlands. The wetlands spread out the flow of water into the stream over a longer period, decreasing flood flows and the peak flood flow that would occur without the wetland. Thus, with less water to overwhelm the stream channel, the height of floodwaters and the area flooded will be reduced.



4-25 Wetland flood storage, a definite benefit

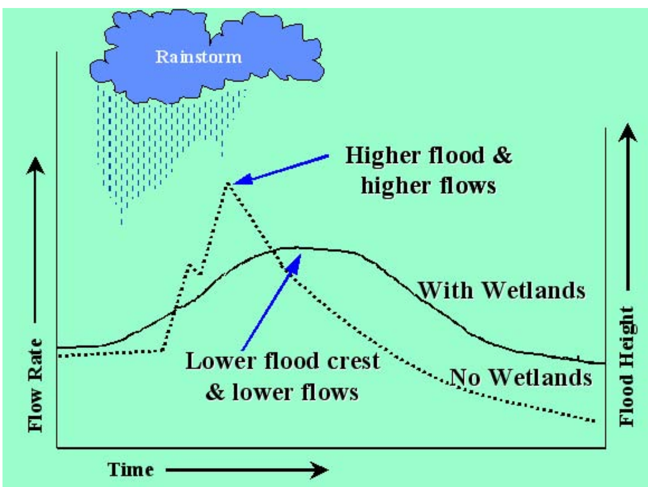


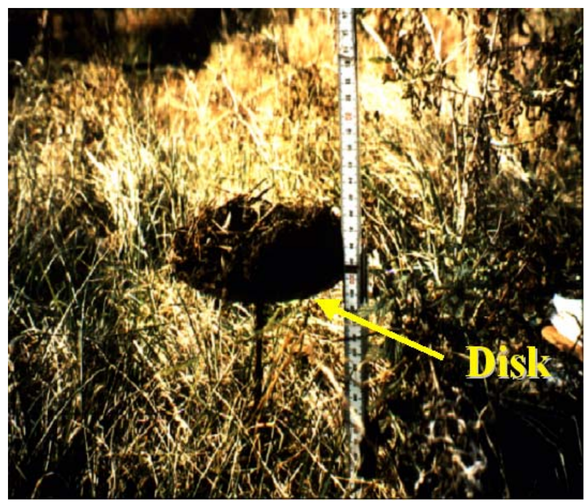
Figure 4-7 Hydrograph

The Charles River in Massachusetts serves as a good example of the beneficial use of wetlands for floodwater storage. The Charles River watershed has approximately 8,400 acres (13 square miles) of wetlands located in the river's floodplain. The lower portion of the river flows right through Boston, posing a serious flood threat to the city. In the early 1970's, the U.S. Army corps of Engineers studied flood control options to protect Boston. The Corps found that the wetlands were so effective at storing floodwater that the best flood protection option was to purchase the floodplain wetlands instead of building structural flood controls, such as levees and detention basins, saving millions of dollars in construction over and above the purchase of the wetlands.

Wetland preservation can thus provide a level of flood control which would otherwise have to be provided by expensive structural facilities and/or dredging operations. As another example, the bottomland hardwood-riparian wetlands along the Mississippi River once stored at least 60 days of floodwater, but, because of wetland loss due to filling and draining, they now only store 12 days' worth. (U.S. EPA)

4-26 Bank stabilization/ shoreline protection - another wetland benefit.

4.4.5.2 Bank Stabilization (Shoreline Protection). Wetland plants typically help stabilize stream banks and shorelines. Both emergent plants, which grow up out of the water, and woody wetland vegetation have a complex root system that helps hold the plants in place in the soft, wet soils. This extensive root structure also helps to keep the soils in place. In areas where shoreline vegetation has been removed, water currents can swiftly erode the exposed soils. Once eroded, these soils can significantly impact stream systems, as discussed in the previous section on The Stream Ecosystem.



4-27 Sediment study being conducted in a wetland.

4.4.5.3 Energy Dissipation. Wetland vegetation also helps reduce erosion by providing resistance to moving water currents and waves. The vegetation slows the flow of water as it is spread out over the wetland and dissipates its energy. Although vegetation is not able to stop all of the erosion associated with water currents, it can drastically reduce the impact by reducing the velocity of the water by up to 90%.

4-28 Do NOT use wetlands as sediment traps!

4.4.5.4 Sediment Trapping. Many wetlands, especially those located along the edges of rivers and streams, act as natural sediment traps. As the water slows from spreading out over the wetlands and meeting the flow resistance of vegetation, the flow energy becomes insufficient to carry the suspended sediment, and the larger and heavier particles begin to settle out. The accumulation of sediment within wetlands is a naturally occurring process, and each wetland has its own sedimentation rate. For, example, one particular wetland may have two inches of sediment deposited each year, while another wetland may typically receive only a quarter of that amount. Studies are conducted to determine the amount of sediment received by wetlands.

This natural sediment trapping wetland function does not mean that wetlands should be used as sediment collection basins. Human activities can seriously increase the natural sedimentation rate and when wetlands fill in, many of the associated benefits are lost.

4.4.5.5 Water Quality Improvement. Wetlands play an important role in improving and maintaining water quality. As mentioned previously, vegetation helps to filter sediments from the water, making the water cleaner and better able to transmit light to underwater plants. These sediments are often nutrient rich, which supports the growth of wetland plants. Materials dissolved in the water also provide a source of nutrients for wetland plants, as well as microorganisms within the soil.

Unfortunately, just as with stream systems, the water quality associated with wetlands is frequently harmed by excess nutrients and chemicals from agricultural and urban runoff and other human activities. These compounds can be dissolved in the runoff or attached to the sediment particles in the runoff. Many of these compounds are filtered from the water by wetlands plants and are even transformed from toxic compounds into harmless compounds. Many wetlands, however, must still process the materials that naturally end up within their boundaries, and excessive materials coming from human sources can easily overwhelm a wetland's ability to improve the water quality.

4-29 Wetlands serve as "riparian buffers"

Wetlands also serve as "riparian buffers" for streams and rivers. The term riparian refers to the portion of the landscape that is located immediately beside the stream or river, while the term buffer refers to a type of filter or barrier. Simply stated, a riparian buffer is any strip of vegetation left intact along a stream or river that can filter out excess sediment, nutrients and chemicals from runoff before the runoff enters the stream.

It is important to note that not all riparian buffers are wetlands because buffers can be constructed in upland areas and contain non-wetland plants. One type of buffer, vegetated filter strips, will be covered in Chapter 5.

4.4.5.6 Ecological Benefits. Wetlands possess a unique combination of physical and chemical conditions that provide ideal habitat for a diverse mix of plants and animals. Many of these wetland organisms have adapted to the unique conditions within wetlands; and if the wetlands are lost, then so are the dependent species that may not be able to survive in any other type of habitat. More than one third of the threatened and endangered species in the United States live only in wetlands. Additionally, many other animals and plants depend on wetlands for survival.

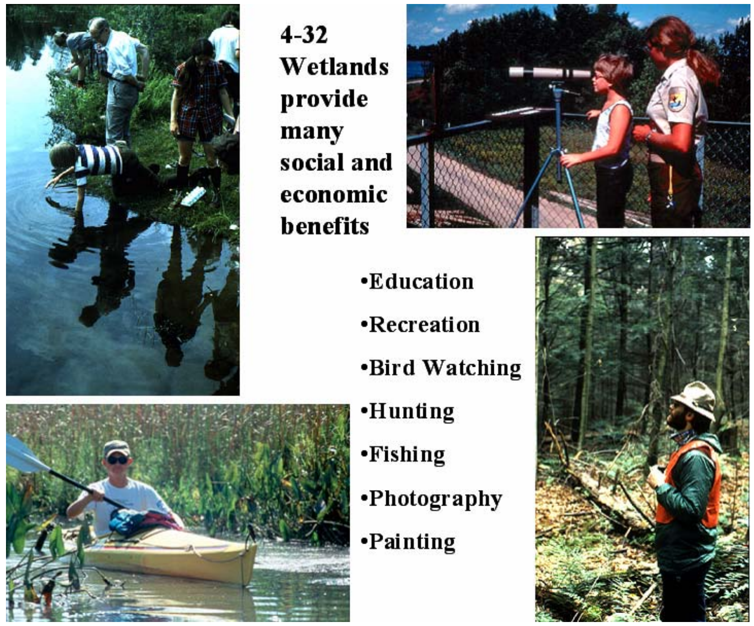
4-30 Wetlands provide vital habitat for a diverse mix of plants, including threatened and endangered species.

Wetlands offer numerous habitat benefits to insects, amphibians, fish, and birds alike. The thick wetland vegetation provides shelter from the elements as well as cover to hide from predators. Wetlands provide habitat for reproduction and developing young for many different terrestrial and aquatic species. The plant material within the wetland also serves as building material for nests and other types of homes. Wetlands provide required habitat for one third of the resident bird population in the United States. Wetlands provide vital habitat for amphibians such as frogs and salamanders, particularly the small forested wetlands, which are only wet during the spring months.

4-31 Wetlands provide Wildlife Habitat: Fish, amphibians, birds, animals. 1/3 U.S. resident bird species dependent on wetlands, especially important for waterfowl.

Wetlands also play an important role in the food web. Wetland vegetation serves as a source of plant material that is eaten by insects, fish, birds, and mammals. These animals, in turn, provide food for the predators. When wetland plants and animals die, their remains break down and decompose, where their nutrients replenish the wetland soils and provide nourishment for additional plant growth.

4.4.5.7 Economic and Social Benefits. Many of the plant and wildlife species that utilize wetlands are economically valuable. Wetlands are home for many commercially important plant species, such as blueberries and cranberries. Bass and other game fish grow and hunt among the wetland vegetation, which also provides critical nesting habitat for most of our waterfowl.



4-32 Wetlands provide many social and economic benefits

Groups such as Ducks Unlimited were among the first to recognize the importance of wetland habitat to ducks and geese. Because of this group's efforts, many thousands of wetlands acres have been protected and restored.

One of the most important benefits of wetland habitat is their use by migratory species. Migratory animals, such as fish, waterfowl and other birds, and insects, use wetlands as places to temporarily rest and replenish food reserves on their long journeys. Many of the wetlands used by migratory animals are relatively small in size, but not in their importance to serve as sanctuaries in our increasingly developed landscape. Because many of these wetland sanctuaries are not large or easily identified, there is a danger that little patches of wetlands will be lost as a result of road maintenance practices and decisions.

Wetlands provide a number of social benefits and opportunities to those who live in and near communities with wetlands. These benefits are largely social in nature, however; just as with stream systems, many of these social benefits also help to support local economies. These economic benefits stem, either directly through creating demand for education or recreation related jobs and services, or indirectly through related spending for gas, lodging, and meals.

Wetlands provide great locations to educate children and adults on a number of different topics. Wetlands provide space that can be used as outdoor classrooms for teaching biology, ecology, natural history, photography, bird watching, painting, arts and crafts, hunting, fishing, trapping, and many other topics and activities.

4.4.6 Types of Wetlands.

There are several systems for classifying [wetland](#) types, and each has its own merits. For our purposes, and ease of recognition in the field, we will discuss a system that divides wetlands into three different categories or types. These three types are classified based upon where they are located in the landscape and are more closely associated with the road environments in the forested areas that are the focus of this manual. Some wetlands form in depressions, some form on slopes, while others form along floodplains.

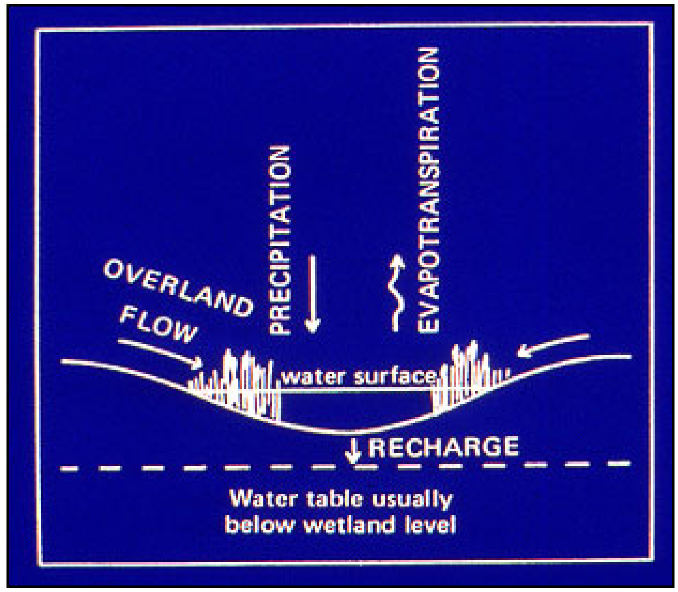
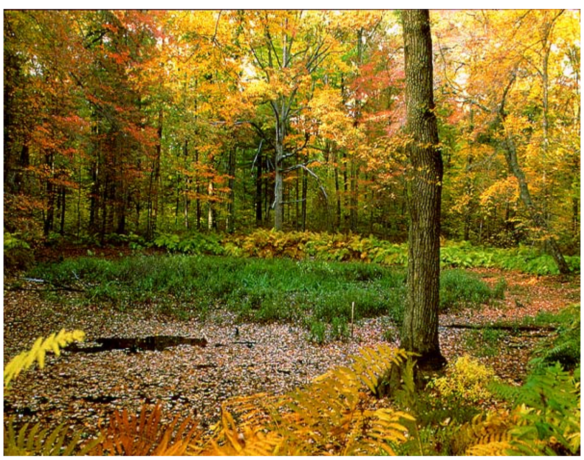


Figure 4-8: Depression Wetland

Depression wetlands form in low lying, bowl-shaped areas. Water enters these wetlands from surface water sources and sometimes ground water sources as well. Figure 4-8 illustrates that these wetlands can have a permanent pool, but in many cases will have various fluctuating water levels depending on precipitation and actually become dry on the surface in times of little or no precipitation. Typically, these wetlands do not have streams or other obvious exits, so water in these wetlands must exit either by evaporation, plant uptake, or by draining into the soil. In forested areas, these "vernal pools" are a prime habitat for a diverse population of amphibians.



4-33 Depression Wetland (Vernal Pool)

Wetlands that form in these depressions are often the most vulnerable to sedimentation caused by human activities because it is difficult for the sediment to be flushed out of the depression. When excessive sediments

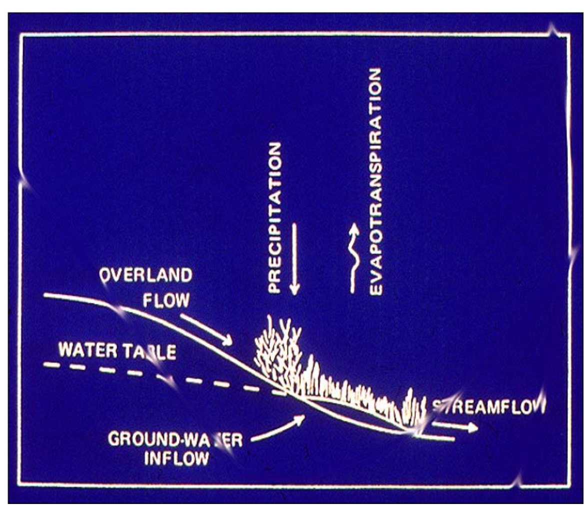


Figure 4-9: Slope Wetland

accumulate in these depressions, it buries plants and animals and can quickly fill in the entire wetland area. This can cause the moisture and soil conditions to change, forcing the plant community to rapidly transition to a more upland mix of species. The wetland plants are then lost along with the wetland and associated benefits.

Sloped wetlands are those wetlands that form on the side of hills and gentle grades. These wetlands typically develop on slopes that have about a 3% grade. This is a common type of wetland found in forested areas where the groundwater emerges at the surface of a slope to supply the wetland, as shown in Figure 4-9. Streams may also enter and leave these wetlands and carry excess sediments during periods of high flows out of the wetland area to locations downhill and downstream. Although still vulnerable to impacts from excess sediment, this ability to remove sediments means that these wetlands are less vulnerable to filling than depression-type wetlands.

4-34 Slope (Seepage) Wetland

Floodplain wetlands are found along the fringes of lakes, rivers, and streams. This wetland type includes vegetation that is commonly submerged by water, as well as vegetation that is temporarily covered with water during periods of high water. This is the most easily recognized and common type of wetland in most areas, as depicted in Figure 4-10. Fluctuating water levels brought about by periodic flooding are critical to the continued survival of these wetlands. Flooding generally occurs during spring months; however, these wetlands can be either dry during much of the year or fairly wet. Sometimes floodplain wetlands also receive water from groundwater sources, and these wetlands tend to be wetter over longer periods. Although all wetlands can be impacted by excessive sediment, sediment and other pollutants in floodplain, wetlands are often only temporarily stored until the next storm event flushes them out.

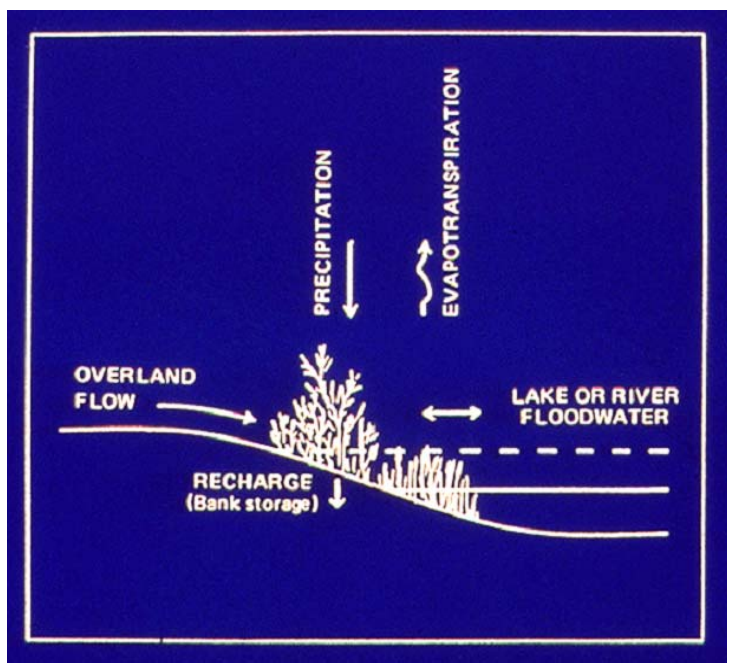
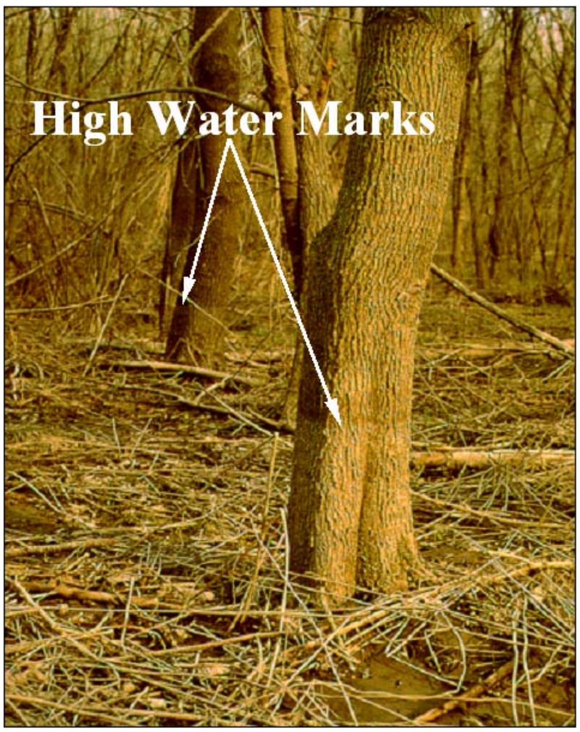


Figure 4-10: Floodplain (Riverine) Wetland

4-35 Floodplain (Riverine) Wetland

4.4.7. Wetlands and Road Maintenance. Now that we have discussed the major benefits and regulatory issues regarding wetlands, it is important to provide some tools to help road personnel recognize wetland areas and provide guidance on what to do when these sensitive areas are encountered during road maintenance activities.

4.4.7.1 Recognizing Wetland Areas. When you hear the word wetland, an image of a marsh with cattails might come to mind. Wetlands, however, are not created equally and they vary in size, shape, position in landscape, amount of water present, mix of plants and animals, appearance, and benefits. While cattail marshes are one kind of wetland, there are many other kinds. Many of the wetlands in forested areas are referred to as forested or shrub wetlands. Although there are a variety of wetland types, several relatively easy clues are available to aid in their identification. These clues are based upon the three criteria for wetlands previously discussed: hydrology (drainage), soils, and vegetation. These clues can be used to help road managers know which portions of their jurisdiction might contain wetlands, as well as identify specific areas that regulatory agencies consider wetlands.



4-36 Wetland Indicators

4-37 Wetland Indicators

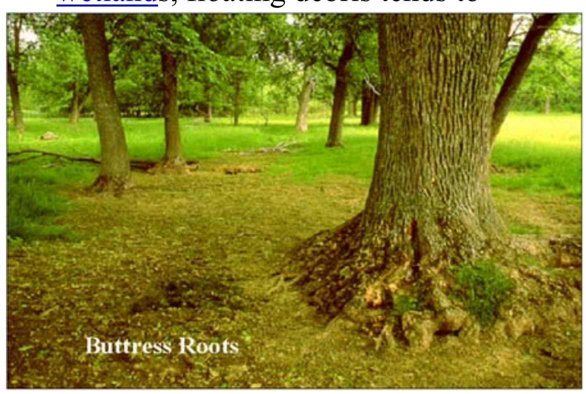
4.4.7.2 Wetland Characteristics: Although each of the wetland types discussed previously is different, they share similar characteristics. Based on the regulatory definition of wetlands previously discussed, each wetland must be wet during part of the year, must have soils that are saturated with water, and contain plants that are adapted to wet conditions. These factors - hydrology, soils, and vegetation - provide characteristics and clues that we can recognize while we are in the field.

Although the presence of standing or flowing water is an obvious indicator of a wetland, many wetlands are only wet during part of the year. There are, however, telltale signs that water has been there. High water leaves silt lines on tree trunks,

4-38 Wetland Indicators

4-39 Wetland Indicators

similar to a ring around a dirty bathtub. These high water marks are a good indicator that you may have a wetland. Fine sediment particles suspended in water frequently settle and are deposited on vegetation, leaving silt-covered or silt-stained leaves, another wetland indicator. When water flows through wetlands, especially floodplain wetlands, floating debris tends to pile up against trees and rocks, forming wrack lines. These wrack lines indicate water once covered this area and again cold indicate a wetland.



4-40 Wetland Indicators

4-41 Wetland Indicators

The roots of trees and plants living in the area provide another clue. Many wetland plants have shallow roots because the roots need oxygen. Soils that are saturated by a high water table do not supply this much-needed oxygen, so the roots remain closer to or at the surface to get the oxygen they need. Wet soils are also very soft and do not provide much support for large trees. Some wetland trees thereby adapt by developing large bases or buttressed trunks and root systems that provide better support. These buttressed trunks indicate soft, saturated soils that may be a wetland.

4-42 Wetland Indicators

The second characteristic of wetlands is saturated soils. Interesting things happen to soils when they become saturated with water. Saturation causes oxygen levels to become depleted, resulting in changes to the soil's normal chemical reactions. In submerged or very saturated conditions, the decomposition of dead vegetation is practically halted because there is little oxygen available to support decomposing organisms and reactions. Without decomposition, partially decomposed plant material accumulates into thick layers of organic soils called peat. This peat is similar to the peat that is dried and sold in stores for use in our gardens. Other wetland soils do not have as much organic matter present and consist mainly of mineral soils derived from parent material. These saturated mineral soils are referred to as hydric soils and sometimes produce gleyed soils that are greenish or blue-gray in color. If these mineral soils form in a seasonal wetland, where the area is alternately wet and dry, metals such as iron and manganese react with oxygen to form oxides (rust) and becomes a mottled soil with orange/reddish brown or dark reddish brown/ black spots in the otherwise gray or greenish gleyed soils. The familiar rather unpleasant rotten egg odor that is sometimes given off by wetlands is caused by the release of hydrogen sulfide gas when wetland soils and sediments are disturbed.

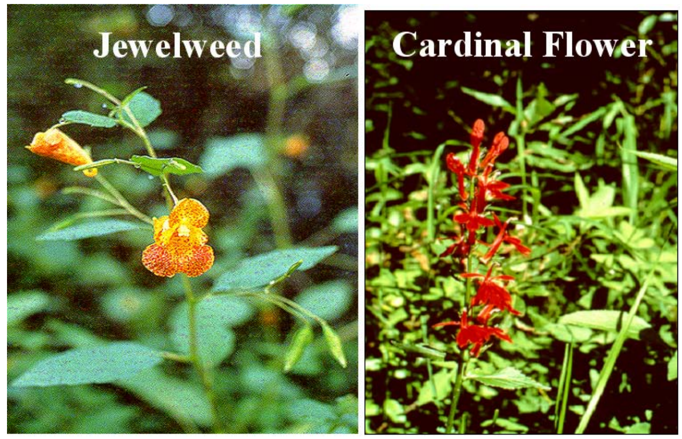
4-43 Wetland Indicators: Common Wetland Plants

4-44 Wetland Indicators: Common Wetland Plants

The third wetland characteristic is the vegetation. Most plants cannot tolerate the wet conditions within wetlands. Some species, however, have adapted to wet habitats. These water-loving wetland plants are referred to as hydrophytes and based on their tolerance for standing water can be further lumped into three groups:

1. Those that are dependent upon permanent water for their survival such as cattails, water lilies, skunk cabbage, buttonbush, and arrowhead. This group includes those plants that most of us would associate with wetlands.

2. Those that can live in standing water but prefer moist soils such as black ash, cinnamon fern, joe-pye weed, jewel weed, cardinal flower, pin oak, and pussy willow.



4-45 Common Wetland Indicator Plants

3. Those that do best in moist to somewhat dry soils such as red maple, catalpa, slippery elm, and arrowwood viburnum.

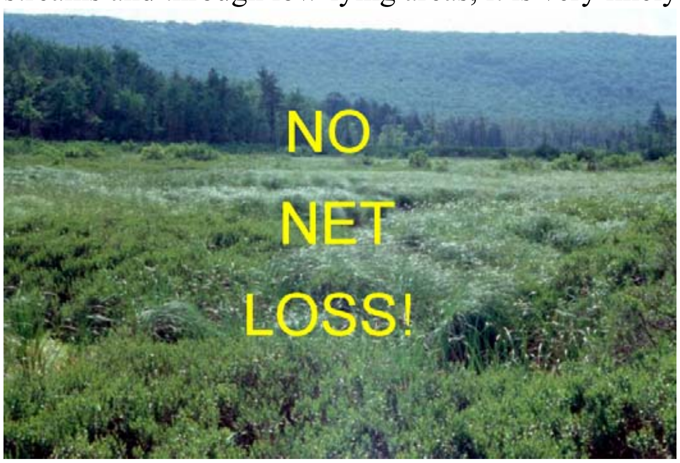
4-46 Less Known Wetland Indicator Plants

Wetland scientists and regulatory personnel use this differentiation of plants to identify and map wetland areas.

It is important to note that not all wetland plants are beneficial. The invasion of purple loosestrife is an example. Just as we are gaining an appreciation for the qualities and benefits provided by wetlands, a terrible foreign invasive plant is destroying our wetlands. Purple loosestrife is a wetland plant with pretty purple flowers that was imported from Europe and Asia. This plant spreads rapidly and, when established, completely out-competes and takes over the wetland within a year. This invasive species became a real problem in New England and quickly spread south and west into many other states.

Purple loosestrife establishes dense, impenetrable stands that are unsuitable as cover, feed, or nesting sites for many wetland animals, including ducks, geese, rails, bitterns, muskrats, frogs, toads and turtles. It also drives out endangered and rare plant species. Purple loosestrife frequently establishes on moist soils that are disturbed by construction activities. Once established, it is very difficult to remove because each plant can dispense 2 million seeds per year. The plant is also able to resprout from roots and broken stems that fall onto the ground or into water. Mowing purple loosestrife often makes the problem worse because it spreads the seeds and scatters bits of plants, which resprout.

4.4.7.3 Encountering Wetlands. Because many of our roads were built along streams and through low-lying areas, it is very likely that wetlands will be a concern for many road managers. It is probably not a question of "if" you encounter wetlands in your work but "when" you encounter wetlands.



4-48 Mandate by Federal Government

As mentioned, there are federal and state laws and regulations governing the protection of wetlands. In many cases, compliance with these laws requires biological and engineering studies and permits with any encroachment onto a wetland. If roadwork interferes with a wetland, the result can be major costs, delays, and potentials for litigation.

A real opportunity exists, however, for local road officials in the realm of wetland regulation. Currently routine maintenance work is usually not a point of enforcement emphasis and, to some degree, permits are waived for such routine items as ditch cleaning. The opportunity is for local road officials to take the information presented here to heart and through their daily maintenance activities prove that no further regulation or increased enforcement is needed in this area. While these opportunities exist, it is critical to remember the possibility of severe penalties for those that do not follow these wetland protection rules.

4.4.7.4 Wetland Strategy. We hope that a strategy of "avoid, minimize, and mitigate" will help road managers as they attempt to work through encounters with wetlands. This strategy involves, in order, avoiding impacts to wetlands wherever possible, minimizing those impacts that cannot be avoided, and mitigating damages where they occur.

4-49 Adopt a Wetland Strategy

Avoid. The ideal way to deal with wetlands is to identify them in advance and then plan improvements and maintenance activities that will avoid impacting these sensitive areas. Traditionally we probably would have drained a whole hillside into a single culvert that discharges water directly into a wetland or stream, dumping more water, sediment, road fines, and chemicals into a wetland than it is capable of handling. Using a combination of the tools presented in this manual, however, we can avoid discharging these excesses into wetlands. For example, stabilizing banks, maintaining vegetated ditches, and installing turnouts and broad-based dips at frequent intervals could prevent significant amounts of sediment and quantities of water from accumulating and carrying material into the wetland. Many tools or practices will be described in subsequent chapters.

Minimize. We recognize the fact that it is not always feasible to avoid impacting wetlands near our roads. In these instances, it is best to minimize those impacts as much as possible. Continuing with the hillside and single culvert illustration used in our discussion of avoiding impacts, we can use a combination of tools to minimize disruption and damages to wetlands. We can set the culvert discharge back from the lowest point and divert water through a vegetated filter strip of grass or other vegetation, thereby trapping excess sediment before it gets to the wetland. Sediment traps can also be used in place of filter strips, but they need to be inspected and cleaned out on a routine basis.

Although only temporary, practices such as the use of silt fences can also provide significant short-term benefits. Straw bale barriers have also been used, but their effectiveness is questionable and are not recommended by the U.S. Environmental Protection Agency. These materials should only be used for short-term activities and must be maintained and cleaned out regularly until the work site is stabilized. These practices and proper use will also be described in more detail in Chapter 5.

Mitigate. Mitigation involves the creation of artificial wetlands in order to replace the lost function and habitat of a natural wetland. This is often an expensive prospect and should only be used as a last resort when avoidance and minimization techniques are insufficient to prevent the destruction of an existing wetland. The biological and engineering studies and design and required permits, along with site acquisition and actual construction, all lend to the extreme costs and time required for mitigation projects. Given the scale and scope of the projects that are likely to be carried out under maintenance activities, it is unlikely that mitigation will be a necessary and/or a viable option.

4.4.7.5 Working with Regulatory Agencies. This section on wetlands is not intended to turn road experts into wetland experts. Rather, its intent is to provide background information on wetlands and help road managers recognize the importance and value of these sensitive habitats. Using the clues discussed above, road managers should be able to recognize areas that might be considered as wetlands. When these potential wetlands are encountered during road maintenance activities, it is highly recommended that local governments contact their local county or state agencies for further guidance on appropriate actions. Local county conservation agencies are familiar with the local conditions and they are familiar with state and federal environmental regulations and agencies, and will be able to help you directly or help you direct inquiries to the appropriate agency.

4.4.8 Wetland Ecosystem Summary. Wetlands are an important natural resource located between full aquatic and upland environments. For an area to be considered a wetland, it must be saturated with water at least part of the year, have soils that have developed under saturated conditions, and contain plants that are adapted to those wet conditions. Many different types of landscape features meet these conditions, of which three were discussed – depression wetlands, slope wetlands, and floodplain wetlands. Most of these areas are relatively easy to recognize using the hydrology (drainage), soils and vegetation clues as potential indicators for a wetland area.

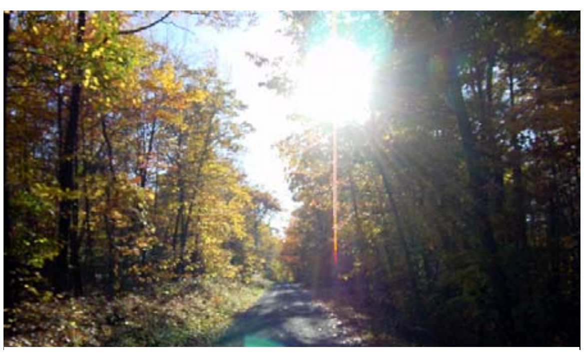
Wetlands benefit natural systems by providing habitat for fish and wildlife and supporting the food web. They also provide important benefits in terms of floodwater storage, bank and shoreline stabilization, sediment trapping, water quality improvements, and opportunities for education and recreation activities. Linked to many of these values are economic benefits as well. Unfortunately, we have been slow to recognize all these benefits and have lost over 50% of our wetlands. Our federal, state, and local environmental regulatory agencies have reacted to this loss and enacted strict measures to protect the remaining wetlands and the benefits they provide. Road managers are advised to adopt a strategy of avoiding wetlands or minimizing the impact and using mitigation only as a last resort as they encounter wetlands in their road maintenance activities.

4.5 The Upland / Forest Ecosystem (Community)

4-50 Uplands produce different challenges for road managers.

4.5.1 Introduction. As the third ecosystem or community , the uplands present drier conditions and different challenges for road managers. In upland areas, nature's purposes may conflict with road maintenance just as they do in stream and wetland areas. Because significant portions of local government budgets are spent maintaining roadside vegetation, road managers need a more complete understanding of plants. A better understanding of the natural reaction plants have toward outside impacts such as their reaction to injury can help road managers develop a strategy to deal with vegetation that takes advantage of nature and natural systems instead of trying to overpower these forces. Trying to overpower nature is unrealistic, costly, and temporary at best.

4.5.2 Plant Basics. In order to effectively manage roadside plants, it is important to understand some basic information including the way plants grow, their life cycles, root structures, and general plant ecology.



4-51 Plants use the sun's energy (light) with carbon dioxide from the air combined with water and nutrients to produce sugars (food) through the process of "Photosynthesis."

4.5.2.1 Plant Growth and Photosynthesis. Unlike animals, which gather energy by eating other plants and animals, plants are able to produce their own food through a complex process called "photosynthesis." If we can recall from the high school science class where we were introduced to this "big word," photosynthesis is the process by which plants convert sunlight, carbon dioxide from the atmosphere, water, and nutrients into sugars. Plants then use these sugars as food, and extra sugar is stored throughout the plant. A familiar example of this energy storage is the sugar maple. The sugar maple stores excess sugar developed during the summer in its roots. As the plant begins to grow in early spring, the sap containing these dissolved sugars is transported to the buds. "Tapping" holes in the trunk of the sugar maple allows collection of this sap, which can be boiled to evaporate the water and concentrate the sugar into maple syrup. This is how the sugar maple got its name, because of the sap's particularly high concentration of sugar.

4.5.2.2 Vegetation Groupings: There are many different types of vegetation. As road managers, we will look at three groupings: woody plants, herbaceous plants, and seedless plants, with a brief discussion of each.

4-52 Plant Groupings

Woody plants contain hard, ligneous fibers in their trunk, stem, and root tissues, which collectively are called wood. Trees (beech birch, maple, oak, white pine, hemlock, etc), shrubs (mountain laurel, rhododendron, low bush blueberry, etc), and many vines (honeysuckle, grape, etc.) are classified as woody plants.

Herbaceous plants are seed-bearing plants that have fleshy stems instead of woody ones. These plants are typically shorter than woody plants and include broadleaf species and grasses. Common herbaceous plants include goldenrod, milkweed, grasses, daylilies, and skunk cabbage. The life span of herbaceous plants varies by species. A discussion of plant life cycles follows in the next subsection.

Grasses are herbaceous plants that have some unique adaptations that make them of special interest to road managers. Unlike other plants that grow at the tips, the growing point of grasses is located at the base, or ground surface; so as new tissue is added, the plant extends itself upward. Many grasses also reproduce in multiple ways. Grasses do flower and produce seeds for sexual reproduction, but many grasses also reproduce and spread by extending horizontal tillers called rhizomes (underground) and stolons (above ground), which act to fill in the spaces between plants, as new grass shoots extend forth from these tillers, as depicted in Figure 4-11. The ability of grass to reproduce in this fashion makes it very valuable as a roadside plant since the frequent mowing of grassy roadsides removes the flowers/seed structures, but not the growing points. The rhizomes and stolons also

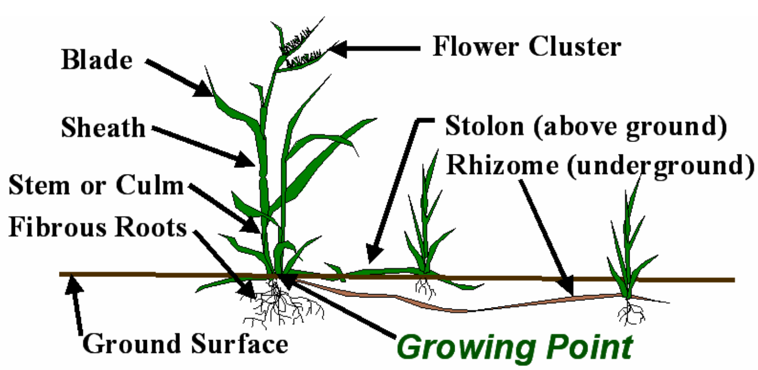


Figure 4-11 Grasses

create a fibrous root system, which holds the soil in place and reduces water runoff velocity.

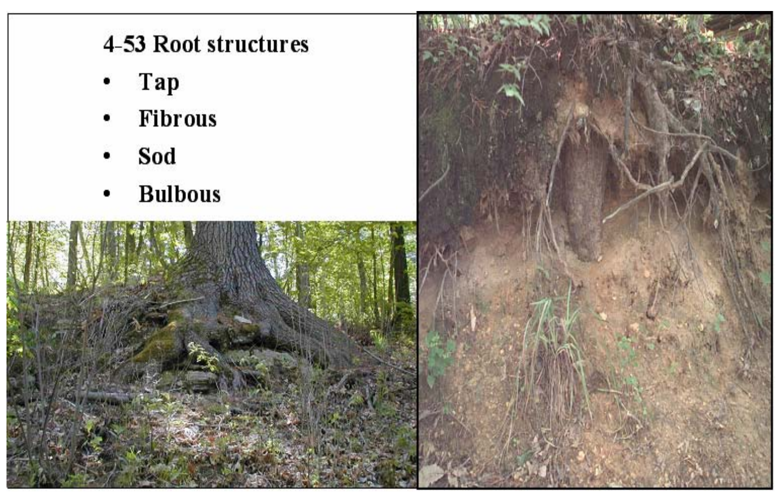
Seedless plants reproduce by tiny spores that drift on the wind, settle on a surface, and begin to grow. Common seedless plants include mosses, ferns, and puffballs. Mosses are often one of the first plants to become established on barren soil. Ferns are very common roadside plants, and many have deep roots that provide good soil anchorage.

4.5.2.3 Plant Life Cycles. In general, herbaceous plants can be grouped in terms of three basic life cycles. The plant life cycle begins with the germination of a seed and is the time required for the plant to grow, mature, produce seeds, and die. One type of plant has an annual cycle because they complete their seed-to-seed life cycle within a year. Some annuals, called summer annuals, sprout from seeds in the spring, flower, produce seeds by the end of the fall, and then die. Winter annuals sprout in the late summer, lay dormant over the winter, flower, produce seeds in the early summer, and then die.

Biennial plants require two years to produce seeds and complete their life cycle. Typically, they germinate in the spring or early summer, grow until fall, and then go dormant for the winter. The following spring, a second growing season begins and the plant grows to maturity, flowers, produces seeds, and then dies during its second fall. Canada thistle is a common biennial plant. If this thistle is continually mowed to prevent flowering and seed production, the plants will die in two years with no replacements to contend with.

Perennial plants live for an indeterminate number of years. Daylilies and skunk cabbage are common perennial plants. These plants keep coming back year after year, typically going dormant in the winter months.

4.5.2.4 Root Structures. Roots provide anchorage for plants and act as a collection system for water and nutrients from soil. The structure of plant roots varies from species to species. Some plants have a large main taproot that penetrates deep into the ground. Tap rooted trees like hickory also have fine feeder roots near the surface of the soil where oxygen is more abundant. Taproots act like reinforcing bars and can be very effective in stabilizing banks that are seasonally saturated and potentially unstable.



Some plants have a fibrous root system. Maple trees are prime examples of plants with fibrous roots. Fibrous root systems provide excellent soil reinforcement.

Some grasses form thick, matted roots called sod, while other grasses grow from a central point and form clumps. Turf type sod grasses act as a natural erosion control fabric by holding soil in place, trapping soil moisture, slowing runoff, and increasing infiltration. Grasses that grow in clumps, like tall fescue, tend to hold soil closer and more securely to the plants' center. With clump type grasses, surface erosion tends to remove soil from between clumps while plant growth builds the clump higher. Clump grasses are thereby not as effective at retarding soil erosion as turf type grasses unless they are seeded densely and are well maintained.

Other plants have a bulbous root system of bulbs or tubers. Daylilies are a bulbous root plant and can be great roadside bank stabilizers without interfering with the road.

4.5.2.5 Plant Ecology. Plants have characteristics that cause them to act very different from animals. These differences involve the way plants gather resources, develop, and grow. We already discussed photosynthesis, the process with which plants produce their own food. In addition, plants are strongly influenced by their stationary, rooted nature. Plants cannot move. They can only react to the environment that exists where they are growing. Animals, by comparison, can simply seek the environment that they like best.

The growth of plants is affected by soil, light moisture, and climatic/weather conditions. Plants require a certain mixture of these factors to thrive, depending on the plant species. While some plants prefer or even require full sunlight to do well, others prefer partial sunlight or shady conditions. Similarly, some plants require lots of water and others prefer drier conditions. For example, the vegetation found along dry, hot ridge tops is very different than the low-lying, lush vegetation found in wetlands. Topography, or the shape of the landscape, is a major factor in plant growth because of its influence on light and moisture conditions. Flat land receives direct sunlight while slopes receive more or less sunlight according to their orientation to the sun. Sloped areas also dry faster because precipitation runs off quickly, with less infiltration into the ground.

Since light, soil and moisture conditions vary across regions, plant species are not uniformly distributed. In areas where the right combination of conditions exist, species that favor those conditions will dominate the landscape. Forest types are commonly named for the species predominant within them. The significant point is that plants grow and thrive in direct relation to the amount of light, quality of soil, quantity of water and type of weather conditions. Where the conditions are similar across the landscape, similar plants will dominate.

Plants are very dependent upon the underlying soil for a number of their critical needs. Although plants' water requirements vary by species, no plant can survive without water. Moisture stored in the soil serves as a steady supply of this vital requirement. Soils also provide nutrients that are necessary for plant growth. Water collected by the roots carries these soil nutrients up into the leaves, where together with sunlight and carbon dioxide, they enable the plant to transform these materials through photosynthesis into sugars for food.

Soils also provide anchorage for plants. By providing support, roots and soil work together to allow plants to grow vertically. By increasing in height, which varies by species, plants can collect more sunlight for greater food production.

As stated, the ability of plants to collect resources and grow is limited by their location since they cannot move. Plants aid themselves in this limitation through recycling. Leaves, branches, and bark fall in close proximity to the plant, where insects, worms, bacteria, and fungi digest them. The decay of this fallen organic matter creates an excellent growth medium. By providing habitat for other creatures, plants also attract nutrients and growth enhancers in the form of animal wastes to their location.

Since plants cannot move like animals, they cannot flee from danger. If they could, there would be a lot fewer trees along our roads with cavities that result from road grader injury. Plants have developed numerous adaptations to deter and prevent insect, animal, and physical damage and even intrusion of other plants. These adaptations range from physical factors, such as fire resistant bark, sticky sap, thorns, and very hard seeds, to chemical factors, such as bad tasting leaves, strong and offensive odors, and toxins released to soil. Some plants, such as ferns, black walnut trees, goldenrod and a few grasses, release toxins into the soil, a process called alleopathy. These toxins released into the soil discourage competing plant species from germinating and growing nearby.

4-54 Plants cannot move, cannot flee from danger.

Earlier it was mentioned that plants form the foundation of a stream's food web. This lead role is carried through to the whole earth's food webs. The ability of plants to effectively transform the sun's energy into another form of energy (i.e., sugar) is one of the basic building blocks of life. Sunlight is the key ingredient, supplying an inexhaustible supply of energy, while the other necessary raw materials for photosynthesis are found practically everywhere in the environment. The availability and abundance of these raw materials explains why plants are so widespread across the planet. Consequently, plants serve as a ready and almost limitless source of food for plant-eating insects and animals, forming the foundation of our earth's food webs.

4.5.3 Understanding Trees. Trees are present along many roadsides. Efforts to manage roadside vegetation consume fantastic amounts of money and effort. In order that road managers might better integrate their vegetation management programs with the natural and relentless growth of vegetation, a better understanding of trees is necessary. A discussion of tree growth and their reaction to injury follows.

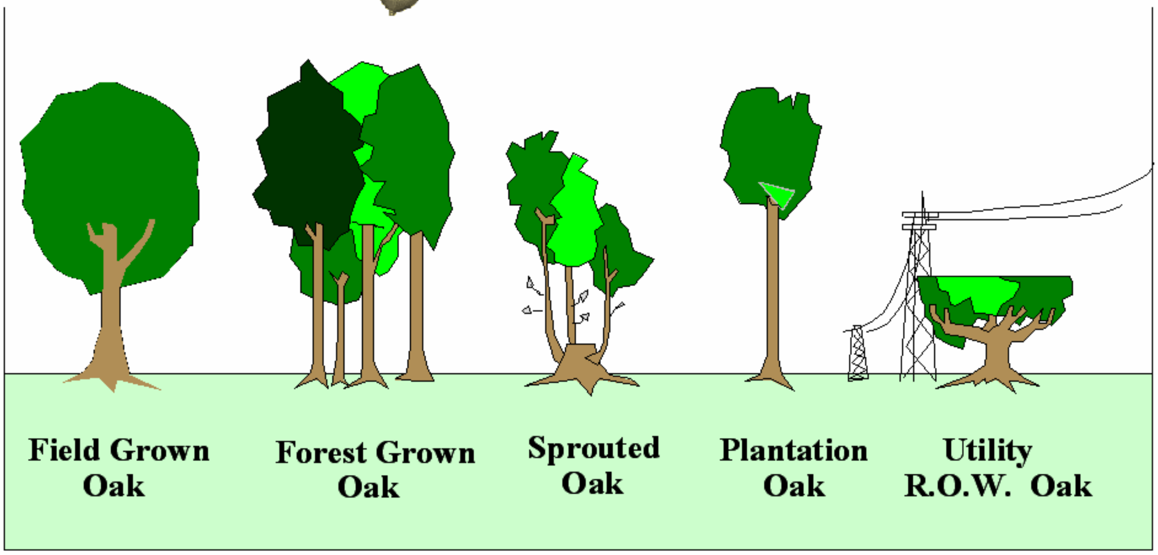
4.5.3.1 Tree Growth. Trees grow in diameter by adding a new layer of wood each year. This new wood forms in the cambium layer immediately behind the inner bark. These annual layers of new growth form the "rings" that most all of us have seen on tree stumps. These rings of growth, if examined closely, can be counted to determine the age of the tree. In addition, the width of the ring indicates the condition of the growing season, a wider ring meaning more growth from a good growing season with plenty of moisture and positive conditions.

The outermost layer of the tree is the bark. Similar to our skin, bark is a protective layer of tissue on the outside of the tree that stabilizes temperature and forestalls insects and disease from damaging the more delicate, actively growing layers beneath it. Bark is adapted to allow the annual increase in diameter of the tree. Some species of trees have bark that can be described as striped or occurring in vertical rows. On trees with this type of bark (e.g., chestnut, oak) the bark accommodates the annual increase in trunk diameter by expanding between the ridges. Other species of trees have smooth bark that actually stretches as the tree expands in diameter. This bark is then replenished in late summer during a period of less vigorous growth. The point here is that bark is very valuable to the tree. It is a highly adapted tissue that performs numerous functions critical to the tree's survival. We need to be aware of the value of bark so that we can avoid damaging it with our maintenance activities.

When trees grow, they increase their height by extending new tissue at the end of branches. This is why a barbed-wire fence nailed to trees does not become higher off the ground with each year of tree growth. The base of the tree is simply growing outward, not upward. The annual increase in diameter is how objects become embedded in trees.

Although all trees add new tissue in the same manner, they do not all look alike. While each tree species has its own growth patterns, individual plants adapt to their surrounding conditions. The oak trees in Figure 4-12 have all taken on different forms based on their specific site conditions. The field grown oak standing alone in full sunlight grows to a different shape than a forest grown oak The field oak must withstand the wind and elements all by itself and therefore needs a lot more structural root support than the forest oak that is sheltered from the wind by surrounding trees. Forest trees grow upwards in an attempt to gather sunlight, resulting in taller trees with fewer low branches. When trees are cut down, some will resprout new growth from the newly cut stumps. These stump sprouts grow in clusters, which result in yet another growth shape. Trees grown under utility wires continuously have their tops removed, producing an unnatural tree shape that is structurally unsound.

Figure 4-12: Plants are affected by their environment.
The same acorn could grow into any of these trees!



4.5.3.2 Tree Injury. As we discussed earlier, bark is the protective layer of tissue on the outside of the tree. When bark is damaged, the tree is permanently wounded. **Trees do not heal, they seal.** Many things can damage the bark of trees. Fire, animals, and equipment are common causes of tree wounds.

Fire is an enemy of some trees and a friend to others. The heat of fire is an obvious enemy to most trees. Some trees, however, require the heat of a forest fire to open pinecones, expose mineral soil, initiate seed germination, or stimulate new growth. Some species, such as scrub oak, have a high oil content, which cause them to catch fire quickly and generate very high temperatures. The hot fires generated when these species burn kills other species, reducing competition. This suppression of species intolerant of fire is an important component in maintaining the diversity and function of many ecosystems.

4-55 Trees do not heal, they seal!

Animals are a major source of injury to trees. Insects burrow under the bark,

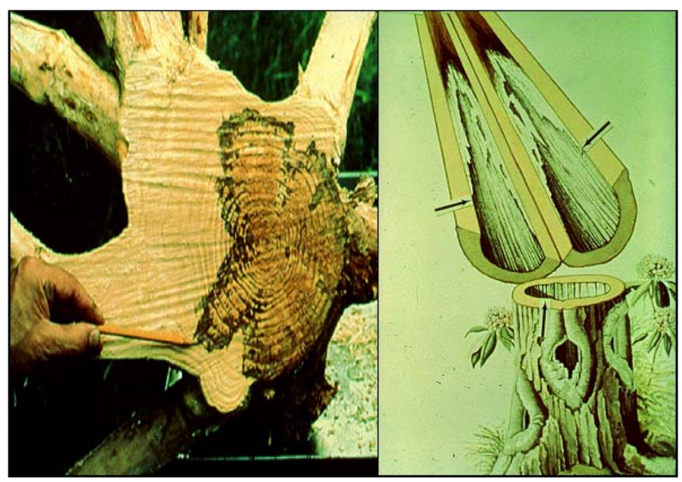
4-56 Fungi attacking wounded tree.

which cuts the trees' lifelines and can allow pathogens into the tree. Insects, like the tent caterpillar, can strip the tree of its leaves, resulting in severe injury or death since the tree cannot process food without green leaves. Birds, such as woodpeckers, peck holes in trees to get bugs and suck sap. Beavers cut trees down for food and building materials, porcupines munch on trees, and deer rub their antlers on trees, damaging the bark.

Road maintenance activities can also cause significant damage to trees. Trees are frequently wounded when heavy equipment bangs into them, ripping sections of bark loose or disturbing the roots. In addition to the physical damage caused by cutting and tearing of the roots, filling and compaction of soils damages roots by cutting off some of their oxygen supply. Any activity that disturbs the tree bark is injurious. Vegetation control measures, which result in indiscriminate injury to roadside trees cause permanent injury. The natural reaction plants have to injury may cause more problems for road managers than the temporary benefit realized by indiscriminant cutting.

4.5.3.3 Tree Reaction to Injury. When trees are wounded, they are not able to heal from the inside as people do. As already mentioned, the growing tissue of the tree is immediately beneath the bark. When a tree is wounded and the growing tissue under the bark is exposed to air, the tissue dries out and dies. Trees attempt to seal these wounds by forming new wood around the edges where bark remains intact. This gradual sealing, or growth of the cambium layer, causes the characteristic callusing around a wound's edges. This sealing process can take years depending on the size of the wound.

As soon as the tree is damaged, natural pathogens attack the exposed tissue. Bacteria and fungi begin to infect and digest the wood. Larger animals like birds and bears dig into the tree to eat the insects that live in the decaying wood. The way trees grow creates ready avenues for rot to spread. When rot invades the tree, it spreads in three directions: radially outwards from the center, vertically up and down, and circularly. The tree rots from the inside out, thus the hollow trees that finally die and always seem to fall onto the road.



4-57 What's happening inside?

4-58 Once rotted, another natural force causes additional damage: freeze cracks.

Even after a tree has sealed the wound, the internal rot does not stop. Rotting wood attracts water. In freezing weather, this saturated wood freezes, expands, and cracks outward, breaking the seal and re-injuring the tree. These frost cracks can extend deep into the center of the tree and, with repeated freeze-thaw cycles, the tree's seal is continuously broken, exposing the new tissue to additional bacteria and fungi.

4.5.3.4 Proper Pruning. While pruning trees is a necessary maintenance activity, it also wounds a tree by creating openings in the protective bark layer. By understanding the way tress grow and react to injury, we can minimize the unintended damage frequently done by ill-advised and improperly executed pruning. Proper pruning of trees becomes one of our environmentally sensitive maintenance practices that will be discussed in Chapter 6.

4.5.4 Plant Establishment and Succession. In our discussion of geology, we talked about geological time scales because natural processes and forces act to change the surface of the landscape over time. The composition of plant communities (i.e., types of species present) also changes over time and is referred to as ecological succession. Ecological succession takes place in a much shorter time frame than geological processes. Like most things in nature, ecological succession is a complex process. There are some basic principles, however, that are important for road managers to understand. Once understood, these natural principles can be utilized to make roadside vegetation management efforts more successful and less costly.

In ecological succession, the composition of a plant community changes as physical and biological processes act to alter the condition of the habitat. As habitat conditions change, plant communities change. Plant succession can be defined as the gradual and orderly process of ecosystem development brought about by change in the community composition and the production of a climax characteristic of a particular geographic region. In other words, plant succession starts with bare earth and, over time, transitions towards mature forest.

Rates of succession vary depending on site conditions. Succession proceeds most slowly in bare, unshaded, nutrient-poor rock and subsoil conditions. On the other hand, disturbed areas where the topsoil is not removed or is saved and re-used are able to revegetate quickly. This is why old strip mines remain barren for so long, while abandoned pasture is quickly vegetated and often quickly forested.

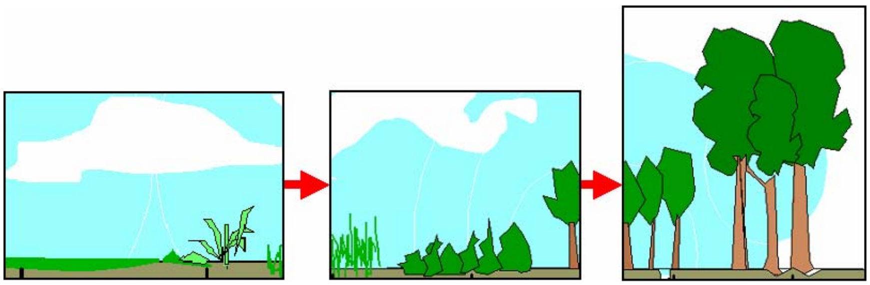
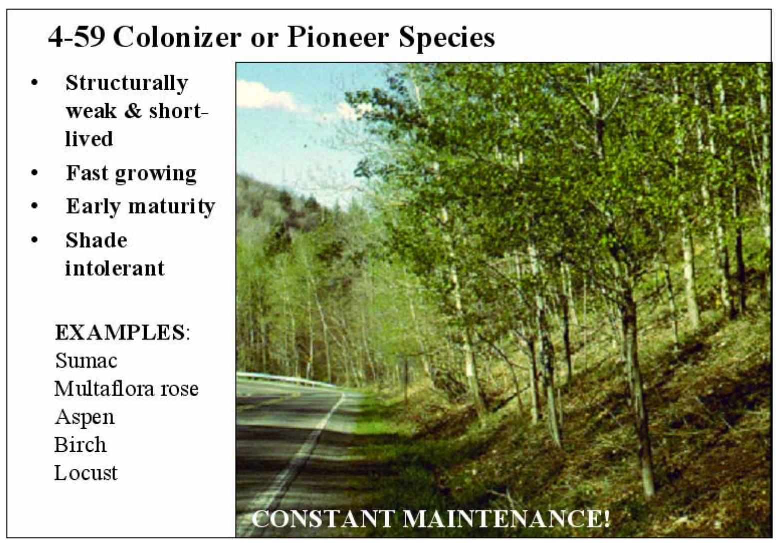


Figure 4-13: Plant Succession

For road managers, roadside trees become a major item within the realm of roadside vegetation management. The following sections describe tree characteristics as they relate to both new and mature successional stages.

4.5.4.1 Colonizer Species. Succession begins with bare soil. The trees that are best adapted to conditions of full sun and nutrient-poor subsoil are called colonizer or pioneer species. Common pioneer species familiar to road managers may include aspen, locust, sumac, grey birch and black locust. These types of trees have certain characteristics for adaptation to the conditions described.



Generally, colonizer species produce massive quantities of lightweight seeds. Although colonizer seeds are not durable, the massive quantities produced and their ability to be transported by the wind assures that some seeds will find barren ground in full sun and germinate. Since they are shade intolerant, roadside banks laid bare during construction and maintenance activities are classic examples of sites prime for colonization.

Although colonizer species are very valuable plants, serving as nature's pioneers, colonizing the harshest environments, and paving the way for successional changes towards intermediate and climax species, they can be problematic for road managers. These trees are fast growing, reaching an early maturity. Thus, they are structurally weak and short-lived. As roadside trees, these factors tend to make them a recurring maintenance problem. These are the trees that will lean out over the road due to their weak structure and end up falling onto the road as wind and storms take their toll or as the trees reach maturity and start to age and die.

4.5.4.2 Intermediate and Climax Species. Ecological succession is a process that never ends. The modification of the soil by the colonizing species results in an environment that is more attractive to sturdier and longer-lived species, causing better suited plants to gradually take over. This rate of transition between species groups and plant communities varies over time. As slow growing, long-lived species become established, the process of succession slows down. As the rate of change slows and stabilizes, we describe it as an intermediate successional stage. Intermediate plant communities offer greater stability for roadside trees. Intermediate stages are typically followed by climax stages, although in many areas few climax forests are found because they were cut down for lumber and have not had sufficient time to progress from intermediate forests to the climax stage. Examples of intermediate/climax trees include oak, hickory, beech, dogwood, redbud, and serviceberry.

4-60 Intermediate/Climax Species

- **Structurally strong & long-lived**
- **Slow growing**
- **Long term for seed production**
- **Shade tolerant**

EXAMPLES:
Oak
Hickory
Maple
Dogwood
Redbud
Serviceberry

Intermediate and climax species typically produce heavy seeds, like oak and hickory, which remain relatively close to their parents. This is an advantage, since the seeds from these species prefer soils that are shaded and rich in organic material. These ideal conditions are typically found underneath the intermediate/climax trees because they shade the ground, trap moisture, and their fallen leaves, branches, and bark reproduce large quantities of organic material.

The slow-growing, strong structure of these intermediate and climax trees make them better roadside plants. Hemlock, beech, and sugar maple all have these characteristics. Because they are stronger than colonizers, they are less apt to lean out over the road or snap under a heavy snow load. The slow growth of these long-lived species also means that they do not need to be trimmed as frequently as the faster growing colonizers.

4.5.4.3 Significance of Plant Succession for Roadside Maintenance. As succession continues and intermediate species become established, the modifications to the soil and environment continue, thereby promoting and encouraging additional intermediate species. As more and more intermediate species establish, the particular site becomes less and less attractive to the colonizer species. This natural process can be used to reduce roadside vegetation maintenance workload by shading out the fast growing, light-dependent colonizers.

Soil laid bare by grading, daylighting and other common maintenance activities is always going to be subject to the natural process of succession. Road managers need to be aware of this process because the natural reaction to many of their maintenance activities creates colonizer growth. In addition, traditional maintenance activities to control the growth of these colonizers typically encourage its re-growth, effectively resetting the clock on an endless cycle of cutting and re-growing.

Although succession proceeds at varying rates, it is ongoing. Even the modest efforts at encouraging the establishment and growth of properly adapted plants along our roadsides can pay large dividends. Properly selecting the plants you remove, the plants you leave, and the species planted can control and accelerate the revegetation of our disturbed roadsides.

The goal for roadside vegetation management should be stability with as little maintenance as possible. A road built through an intermediate or climax plant community can be less costly to maintain if we learn how to use the forest system to our advantage. The use of the forest system to benefit road maintenance will be further discussed in Chapters 5 and 6.

4.5.5 The Importance of Plants. The fact that plants form the basis of the earth's food webs was already mentioned. In addition to food, plants provide valuable habitat for wildlife. Plants also provide numerous other benefits to human society as part of their role in ecology. These benefits are widespread and occur wherever plants grow, whether in forests, fields, or along our roadways. Many of the benefits have been discussed previously, so the following descriptions will both summarize and add to the benefits that plants provide.

4.5.5.1 Ground Cover and Erosion Prevention. Plants act as groundcover and prevent erosion in several ways. The foliage and physical structure of the plant reduces the direct impact of raindrops on the soil. Plants hold soil in place with their network of roots. Plants also act to slow surface flow, decreasing erosion energy, trapping sediment, and allowing more infiltration into the soils. The shaded or partially shaded soils under plants are cooler and more moist than more exposed soils and therefore more permeable to rainfall. Obviously, the more water that soaks into the ground, the less that runs off and causes erosion problems.

Plants also soak up water out of the soil. This process dries the soil and decreases the lubricating effect of water and again decreases the amount of runoff and erosion.

4.5.5.2 Air Conditioning. The water drawn up from the soil and into and throughout the plant carries the nutrients for plant food production. Excess water is then evaporated from the leaves and released into the atmosphere. This release process, called transpiration, cools the leaves and the surrounding atmosphere. Just as perspiration cools us, transpiration cools the plants, adding humidity and cooling the air. Trees are nature's air conditioners, which is a great advantage to humans. Where would you rather be on a hot summer day: a paved parking lot at the mall or sitting on a park bench under a giant oak tree?

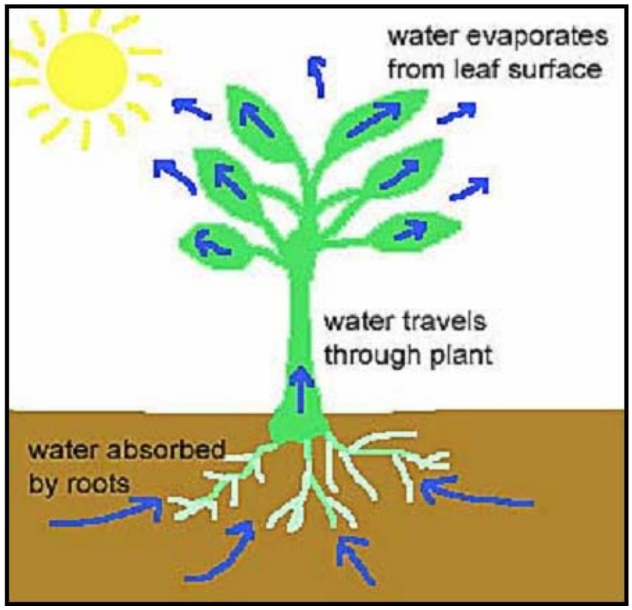


Figure 4-14 Transpiration

Plants also provide shade that cools the area by reducing sunlight and the drying effect that it has on soil. In this way, plants act to modify the environment to their own benefit, too.

4.5.5.3 Air Purification. The air cleaning characteristics of plants improves the quality of air. As part of the process of photosynthesis, plants take carbon dioxide from the air as a raw material and give off oxygen as a natural by-product. Animals, including humans, require oxygen to live. When animals inhale, their lungs extract the oxygen from the air and exhale the carbon dioxide. By using the by-products of each other's life processes, plants and animals are fundamentally tied to one another, with each providing a critical, life-giving element for the other.

Plants can also provide physical cleaning of the air. Airborne particles are filtered out as air drifts through vegetation. The leaves act to slow the air velocity down, which allows dust to settle. This is why leaves on roadside trees are commonly coated with dust (until it rains and the dust is transported as sediment to the nearest stream or wetland).

4.5.5.4 Water Purification. The value of wetland plants in water quality was discussed in the section on the Wetland Community. Plants soak up water along with any chemicals and other contaminants that may be dissolved in the water, thereby having a cleansing effect.

4-61 Value of Plants: Aesthetics and Economics

4.5.5.5 Aesthetics and Economics. The first impression visitors get of a community is what they see along the roads. Nicely vegetated and diverse roadsides give an impression of comfort and relaxation. Management of roadside vegetation in harmony with nature benefits us visually and economically. It looks good (better for tourism), and it is easier on the local government budget than an unending cycle of invasive growth and removal.

4.5.6 Upland Ecosystem Summary. The management of roadside vegetation is traditionally an expensive and time-consuming task. A general understanding of the way plants grow and react to our maintenance efforts can help road managers to utilize natural processes to reduce the frequency and cost of vegetation management efforts.

In this section, we talked about plant basics, their growth factors and the process of photosynthesis that allows plant to produce their own food. We discussed different groupings of plants and their characteristics, along with the different plant life cycles. We looked at plant root systems and their importance in soil stabilization. We then looked at plant ecology and how plants are influenced by light, soil, water, and climate, factors that vary from site to site. Changing any of these primary influencing factors can have a dramatic effect on the plant community. We discussed how plants react to injury, particularly roadside trees. We covered plant succession, differentiating between the colonizer or pioneer plants that are high maintenance items and the intermediate and climax species that can reduce maintenance.

Finally, we discussed the overall importance of plants, noting their value for soil reinforcement and erosion prevention, as air cleaners and conditioners, as water cleaners, and for general roadside aesthetics.

As road managers, the more we know about plants and natural systems, the more we can use this knowledge toward a more efficient and effective roadside vegetation management program.

4.6 Summary of Natural Systems

Because dirt and gravel roads are located amidst natural biological systems, the stream, wetland, and upland/forest communities that these roads pass through are likely to interact with the daily maintenance and operation of these roads. These interactions can affect both the road and the natural systems. Therefore, if road managers are to provide better roads while complying with today's complex environmental regulations, it is important for them to understand the importance of these natural systems and some of the major processes that take place.

This chapter contains a significant amount of information on natural biological systems. This information should be useful as we move into the remaining chapters and begin to discuss environmentally sensitive maintenance practices that will benefit both the road and the environment and help prevent erosion, sediment, and dust pollution. We will spend less money and do less environmental harm if we understand and work with, not against, nature and the natural systems.

These natural systems have been discussed and summarized individually, but it is critical to note that these systems do not exist individually. Just as they interact with roads, these natural systems interact and depend on each other, with processes and functions blending across the boundaries between each system, making up the total environment in which we live and work. Remember, as John Muir put it, “When we try to pick out anything by itself, we find it hitched to everything else in the universe.”